Optimizing mental health care processes through data driven operations management

T. C. de Jong
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Colophon

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Preface

Dear reader,

This report is the final product of my thesis project for the Bachelor of Science *Industrial Engineering and Management* at the University of Twente. The project was conducted at Pro Juventus, a mental health care provider. It was a refreshing change of pace to leave the lecture halls behind and work with real people and real problems, as well as leaving the more common industrial engineering domains of factories and supply chains to explore the Dutch mental health care sector.

First of all, I want to thank Ronald Graveland and Dineke Smit for being my supervisors at Pro Juventus. They offered me insight into the inner workings of the organization, and always had me leave our appointments full of energy and new ideas. They also offered me the opportunity to do my research in a sector I hadn't experienced before, which really broadened my horizons.

I also want to thank Maartje Zonderland and Erwin Hans for their advice and patience in their role as supervisors for the university. I had a slow start but was given a second chance, which I am most grateful for.

An honorable mention goes out to team *Advice and Support* at Pro Juventus, the colleagues whom I shared an office with, for speaking their minds about the organization, creating an enjoyable workplace and answering many of my questions. Especially Sabine Staring, Adrie van den Hoogen and Annet Braakman, you have been most helpful to me on countless occasions. I will miss the daily walks during our lunch breaks!

Finally, I'd like to thank my girlfriend and my family for their support and encouragement during this project.

I hope reading this report gives you as much information and enjoyment as I experienced during my time writing it.

Yours truly,

Casper de Jong

Managementsamenvatting

Pro Juventus is een Nederlandse ggz-instelling met hoge beoordelingen door hun patiënten. Pro Juventus biedt ambulante geestelijke gezondheidszorg, met klinieken in Kampen, Wezep, Wijhe en Ommen. Pro Juventus heeft momenteel weinig inzicht over hun patiëntenpopulatie, aankomst van nieuwe patiënten en ontslag van patiënten. De organisatie hoopt dat het analyseren van de elektronische patiëntendossiers ondersteuning kan bieden voor het primaire proces: het verlenen van geestelijke gezondheidszorg. Het kernprobleem van dit onderzoek is *"Hoe kan op data gebaseerde operations management het primaire proces van Pro Juventus ondersteunen?"*

Pro Juventus is gebonden aan de *Zorgverzekeringswet*, de *Jeugdwet* en de *Wet kwaliteit, klachten en geschillen in de zorg*. Deze wetten bepalen hoe Pro Juventus gefinancierd wordt en borgen kwaliteit en patiëntrechten. Zorg bij Pro Juventus kan in die groepen verdeeld worden: jeugdzorg, basis ggz (GB-GGZ) en gespecialiseerde ggz (G-GGZ). De grootste belanghebbenden zijn zorgverzekeraars, behandelaren, ondersteunend personeel en de eigenaar. De elektronische patiëntendossiers bevatten informatie over zorgpaden, patiëntgegevens en afspraken. Er zijn veel beperkingen op de kwaliteit van de data, bijvoorbeeld door jaarlijkse veranderingen in wetgeving, incorrecte registratie en aanwezige testdata tussen echte gegevens.

Pro Juventus draait momenteel verlies na jaarlijkse omzetgroei sinds 2015. De productiviteit van behandelaren is 61% in de periode van januari 2019 tot en met juli 2019. Dat is lager dan de door management gehanteerde ondergrens van 75%. Patiënttevredenheid wordt bijgehouden met een enquête. Met 25,9% reacties wordt een gemiddeld cijfer van 8.1 op een schaal van 1-10 behaald. De wachttijden bij Pro Juventus variëren tussen de 4 en 12 weken afhankelijk van de kliniek en het zorgtype.

Management geeft aan informatie over de zorgzwaarte van nieuwe patiënten te willen. De eigenaar wil ook bewuster kunnen kiezen in welke volgorde de behandeling van patiënten gestart wordt.

Uit analyse van de gegevens van de tweede helft van 2018 blijkt dat er 1.197 unieke jeugdpatiënten zijn, 319 unieke GB-GGZ-patiënten en 2.997 unieke G-GGZ-patiënten. Jeugd- en GB-GGZ-patiënten tonen vergelijkbare karakteristieken, terwijl G-GGZ-patiënten meer dan de dubbele hoeveelheid afspraken per patiënten zien en tweemaal het aantal multidisciplinaire overleggen per patiënt. De hoeveelheid administratieve taken en no-shows zijn vergelijkbaar voor alle drie de groepen.

Er is een zeer beperkt aanbod aan literatuur over operations management in de ggz. Door Pro Juventus te classificeren volgens taxonomie uit de literatuur, volgt dat Pro Juventus het verzorgingsgebied dekt met meerdere klinieken. Er is een beperkte dienstenmix door geen opname of forensische zorg te bieden, waardoor het primaire proces simpeler wordt. Er is geen vrije inloop van patiënten, en er is een wachtrij per behandelaar. Patiënten worden op volgorde van wachttijd van de wachtlijst gehaald. Patiënten worden niet dynamisch aan een andere behandelaar toegewezen, tenzij een behandelaar ziek is.

Er is zeer weinig informatie over het voorspellen van patiëntontslag in de ggz. KPI's voor zo'n voorspelling kunnen bepaald worden door behandelaren te interviewen en hun beslissingsproces omtrent ontslag te begrijpen. Op basis van deze interviews kan gerichte dataverkenning gedaan worden of nieuwe data verzameld worden.

Voor het bepalen van de voorspellende waarde van een diagnose op de zorgzwaarte van de patiënt zijn 503 patiënten geselecteerd van de totale populatie. 17 diagnoses bestaande uit 8 of meer bijbehorende patiënten (396 in totaal) zijn vergeleken met elkaar en de totale populatie. De resultaten toonden grote variantie en weinig statistisch significante verschillen bij een vergelijking van de 95%-betrouwbaarheidsintervallen voor verschillende indicatoren. De grote variantie en beperkte significante verschillen beperken het nut van de voorspellende waarde van de primaire diagnose op de zorgzwaarte.

Een implementatieplan voor data-analyse bij Pro Juventus is voorgesteld binnen een budget van €25.000 en een horizon van twee jaar. De stappen van data-analyse zijn toegepast op het verkrijgen van de door management gewenste informatie, met voorstellen voor omschrijvende en voorspellende analyses. Verkennende data-analyse wordt voorgesteld als aanpak om nieuwe waardevolle voorspellers te vinden, evenals andere informatie die voor management nuttig is. Het plan sluit af met het advies een parttime analyst van een detacheerder te huren, en biedt een tijdlijn voor stappen om tijdens de implementatie uit te voeren.

Management summary

Pro Juventus is a Dutch mental health care provider that is currently highly rated by its patients. Pro Juventus offers mental health care on outpatient basis, operating clinics in Kampen, Wezep, Wijhe and Ommen. Pro Juventus currently has little insight in their patient population, arrivals and discharges. The organization hopes that analyzing their electronic health records can support their primary process of providing mental health care. The core problem of this research is *"How can data driven operations management support the primary process of Pro Juventus?"*

Pro Juventus is affected by the *Health Insurance Act*, *Youth Act* and *Healthcare Quality, Complaints and Disputes Act*. These acts dictate how Pro Juventus is financed, safeguards quality and patient rights. Care at Pro Juventus can be classified in three groups: youth care, general adult mental health care (GB-GGZ), and specialized adult mental health care (G-GGZ). The most important stakeholders are health insurers, practitioners, supporting staff and the owner. The electronic health records contain data about care paths, patient details and appointments. There are many limitations to the data quality such as annual regulatory changes, incorrect registration and test data being present in the database.

Pro Juventus is currently operating at a loss after seeing consistent revenue growth since 2015. Practitioner productivity is below management's lower limit of 75%, at 61% for the period from January up to and including July of 2019. Patient satisfaction is tracked through an internal survey. At 25,9% response rate the average grade is 8.1 on a 1-10 scale. The waiting times at Pro Juventus vary between 4 and 12 weeks depending on the desired location and type of care.

Management has said they want information on the care complexity for new patients. Additionally, the owner wishes to make more deliberate decisions on which patients to start treatment for.

An analysis of patient and appointment record shows for the second half of 2018 shows there are 1.197 unique youth patients, 319 unique GB-GGZ patients and 2.997 unique G-GGZ patients. Youth and GB-GGZ patients show similar characteristics over evaluated performance indicators, while G-GGZ patients show more than twice the number of appointments per patient and twice the number of multidisciplinary meetings per patient. Administrative activities and no-show rates seem similar over all three groups.

There is very limited literature available about operations management in mental health care. Classifying Pro Juventus in a taxonomical framework from literature, we see Pro Juventus opting to spread multiple clinics over its service area. It has limited its service mix by not providing inpatient care and forensic care, simplifying the primary process. There are no walk-in patients, and there is one queue per practitioner. Patients are taken from the waiting list by a "first come, first serve" doctrine. Patients are not dynamically reassigned unless a practitioner is sick.

Data analysis can be classified in three groups. The first group is the descriptive group, providing descriptions of collected events. Examples are counts or ratios of various indicators. Predictive analytics try to predict trends based the descriptive data. For example, simulations or forecasting. Prescriptive analytics build on de predictive analytics by enabling different kinds of automation. In this case the analytics would suggest the best outcome. Literature establishes four stages of data analytics. The capture stage collects raw data. The transformation stage clean and prepares this data for analysis. The analysis stage performs the desired analysis. The consumption stage presents the data in an easy to interpret format. Literature warns that electronic health records are generally poorly suited for analytics, because of inhomogeneous data storage.

There is very limited information on predicting discharges in mental health care. KPIs for predicting discharge could be determined by interviewing practitioners to understand their discharge decision process. Based on these interviews, exploratory data analysis could be conducted or more data could be collected.

For evaluating the predictive value of a patient's diagnosis on their care complexity, 503 patients were selected for the total population. 17 diagnoses with 8 or more patients (396 total) were compared against each other and the total population. Observations showed high variance and only few statistically significant differences when comparing 95% confidence intervals for each group's mean over various indicators. The high variance and limited significant differences limit the use of primary diagnosis as indicator of care complexity.

An implementation plan for data analytics at Pro Juventus is proposed within a budget of €25.000 and time horizon of two years. The stages of analytics are applied to achieving management's desired information, with suggested descriptive and predictive analytics. Exploratory Data Analysis is suggested as approach towards finding new and more significant predictors than the primary diagnosis, as well as other information that is useful for management. The implementation plan concludes with the suggestion to hire a part-time analyst from a secondment agency, and a timeline for activities to complete during the implementation.

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1 Introduction

This chapter opens with a brief context description in Section 1.1, followed by the research motivation in Section 1.2. Next it describes the problem context in Section 1.3, defines the research objective in Section 1.4 and concludes with a list of research questions in Section 1.5.

1.1 Brief context description

The Dutch mental health care (GGZ) has been under increasing pressure during the last few years (van Unen, 2018). Care providers have long waiting lists (Radar, 2018) and there is a nationwide shortage of practitioners (GGZ Nederland, 2018).

Pro Juventus is a quickly growing mental health care provider that is affected by the described difficulties. Pro Juventus was founded in 2009 and has opened clinics in Kampen, Wezep and Wijhe, with a new one in Ommen opened during this research. The primary process is providing mental health care for both children and adults. At Pro Juventus there are different types of practitioners with different specializations. Depending on the patient's needs, multiple practitioners can be involved in diagnosis and treatment. Supporting processes are not yet fully developed because of the rapid growth. This causes Pro Juventus to have limited insight about how their resources are managed, how to schedule patients and how to forecast future workload when accepting new patients.

Pro Juventus believes analyzing the data from electronic patient files will play a key role in combining growth with high quality care. Pro Juventus is running into capacity limitations as well as very uneven work distribution among practitioners. Because the organization has no prior experience with this sort of problems, the research will be performed during an internship by a University of Twente graduation candidate.

1.2 Research motivation

The problem owner is director and psychiatrist Ronald Graveland, who is also the founder and owner of Pro Juventus.

Pro Juventus is currently highly rated by its patients (Patiëntenfederatie Nederland), and strives to keep that unchanged. However, better understanding of internal processes is believed to be required. It is currently unknown how long patients will need treatment, which makes it difficult to provide accurate estimates for new patients on the waiting lists. Additionally, the workload individual patients put on the different types of practitioners is unknown.

Mr. Graveland states the organization needs more insight in their patient arrivals, associated workload and patient discharges. This should help provide better care, shorten waiting lists and balance the workload on practitioners. Management suggested creating personas for recurring patient types, each representing a certain amount of various resources. These personas would be based on data from their electronic patient files.

1.3 Problem description

Figure 1 represents the problem cluster of Pro Juventus at this start of this research. The green block at the bottom represents the main problem the problem owner hopes to solve. All other blocks are interconnected subproblems. The orange block is an external factor and cannot be influenced within the scope of this project. This section explains each block.

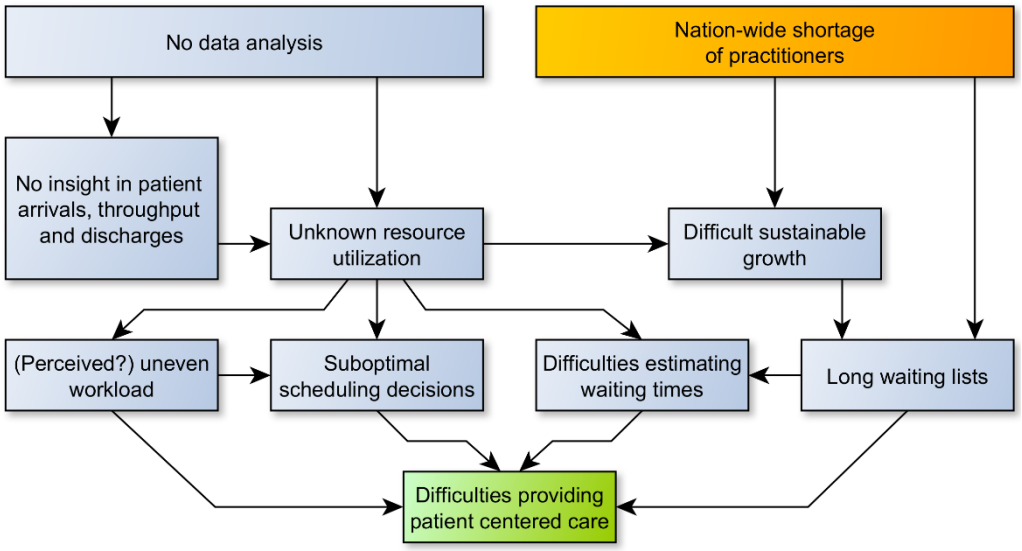


Figure 1 – Problem cluster Pro Juventus

1.3.1 No data analysis

There is no recurrent data analysis that helps the organization in its decision making. Data from the electronic patient files is automatically collected as care is provided, but currently not examined for patterns or signaling problems.

1.3.2 Nation-wide shortage of practitioners

There is a nationwide shortage of mental health care practitioners (GGZ Nederland, 2018) (Trouw, 2019a) (Trouw, 2019b). The shortage makes it hard to staff new clinics and fill vacancies at existing clinics. New staff tend to be recent graduates and are often inexperienced.

1.3.3 No insight in patient arrivals, throughput and discharges

Patients come and go as they do, but there is no overview of average time spent in the system, resources utilized, time from intake until discharge, and similar performance indicators.

1.3.4 Unknown resource utilization

It is currently not known which groups of practitioners face the most work relative to the available FTEs. This hinders capacity-related decision making, such as which types of practitioners to hire or which rooms are available at what time.

1.3.5 Difficult sustainable growth

Because of the lacking knowledge about resource utilization as well as the nationwide shortage of practitioners, it is hard to decide when and how to expand. Additionally, the types of practitioners most needed might not always be available. This problem is considered outside of the scope of this research.

1.3.6 Uneven workload

It is uncertain whether the workload is really distributed unevenly, but practitioners feel like that is the case. This requires further evaluation to determine if this is a factual or perceptual problem.

1.3.7 Suboptimal scheduling decisions

Currently, patients are taken off the waiting list at a “first come, first serve” basis. This means the resource availability such as relevant practitioner workloads are not considered when taking in new patients. It also does not consider the urgency of patient’s complaints.

Because there is no readily available information about the workload distribution, resource availability and workload caused by taking in new patients, the effects of starting a patient’s treatment on the rest of the organization are unknown.

1.3.8 Difficulties estimating waiting times

Because there is no readily available information about the resource availability and estimated discharges of existing patients, it is difficult to estimate when new patients can start treatment.

1.3.9 Long waiting lists

Because there is an incredibly large demand for mental health care, combined with nationwide shortage of practitioners, the waiting lists are very long.

1.3.10 Difficulties providing patient centered care

All the preceding problems mean the organization is under a lot of stress, while at the same time it does not have the information it needs to make decisions that would lighten the load. This makes it more difficult to keep prioritizing the patient’s needs.

1.4 Research objective

The selected core problem is the lack of data analysis. The organization can more easily measure its performance and make better decisions with tools such as a dashboard with relevant KPIs or automated performance reports. Management is lacking information they need to support their decision making. For example, main practitioners are not automatically alerted of patients that undergo excessively long treatment.

Because of how broad this core problem is, the scope should be limited to what is relevant for understanding how patients move through their care path from intake to discharge. This most closely resembles what was originally requested by Pro Juventus, as well as providing the biggest expected results relative to the required investment.

Therefore, the core problem is redefined as:

Pro Juventus currently does not apply data driven operations management to support their primary process.

The research objective is to solve the core problem. That means answering the following question:

“How can data driven operations management support the primary process of Pro Juventus?”

1.5 Research questions

This section lists research questions related to the research objective with context about their relevance.

I. In which context does Pro Juventus operate?

A good understanding of Pro Juventus their environment is required for problem analysis or designing interventions. The following sub questions provide context for this research project:

A. How is mental health care regulated in the Netherlands?
Mental health care regulation is a significant factor aspect of Pro Juventus its context.

B. How is the organization structured?
The structure helps understand the organization and limits potential solutions.

C. How are the processes of Pro Juventus defined?
Thoroughly understanding current processes helps finding room for improvement as well as estimating solution effects.

D. Who are the stakeholders of Pro Juventus?
Understanding who the stakeholders are aids in decision making, designing solutions, and gathering support when implementing solutions.

E. What are the contents and limitations of the electronic health records?
Electronic health records are the main source of available data. Data driven operations management will likely be based on this data. Understanding the data its contents and limitations is required before drawing conclusions from it.

II. What is the operational performance of Pro Juventus?

A benchmark of the current situation is required to evaluate effects of interventions. The following sub questions need answers to determine the current performance:

A. How does Pro Juventus currently measure its performance?
Pro Juventus is measuring only a few aspects of their performance.

B. Which information does management think they need?
A few of the problem owner's wishes are mentioned in Section 1.2. This research question should expand on those first wishes.

C. What is the current workload per type of care?
Limited observations and anecdotes imply an uneven workload on different types of practitioners. Quantifying the workload clarifies if the workload is indeed uneven and helps the problem owner make better staffing and scheduling decisions.

III. What does literature say about operations management in mental health care?

Literature describes the current state of the art. Consulting this body of knowledge aids in understanding problems, designing better solutions and avoiding known pitfalls.

A. Which KPIs should be monitored during a patient their treatment to improve discharge prediction accuracy?
If certain data helps improve the discharge prediction accuracy, the organization will have a better insight into the workload of active patients and when it can accept new patients from the waiting list.

IV. To what extent do patients with the same initial primary diagnosis place the same workload on the organization?

Answering this question helps with forecasting the workload added by starting treatment of new patients. This might lead to a new way of prioritizing patients on the waiting list, weighing in current resource utilization. Additionally, if patients can be classified by their primary diagnosis sufficiently accurately, this simplifies answering other research questions as well as supporting decision making.

2 Context analysis

This chapter answers Research Question I: “In which context does Pro Juventus operate?” by answering its related sub questions in the sections described by Table 1. The chapter concludes with a summary of the most important aspects in Section 2.6.

Table 1 – Section numbers per sub question of Research Question I

Section	Sub question
2.1	A. How is mental health care regulated in the Netherlands?
2.2	B. How is the organization structured?
2.3	C. How are the processes of Pro Juventus defined?
2.4	D. Who are the stakeholders of Pro Juventus?
2.5	E. What are the contents and limitations of data in the electronic health records?

2.1 Mental health care regulation

Mental health care in the Netherlands is financed through five acts (GGZ Nederland, sd). A sixth act manages quality and patient rights. Table 2 provides a summarized overview of all these acts. These acts dictate requirements for mental healthcare providers to be financed by (local) government and health insurers. They include requirements on diagnosis according to international standards, how care paths are organized, quality requirements and safety requirements. Most of these acts were introduced in 2015 when the national healthcare system was changed.

Table 2 – Dutch mental health care acts

Act name	Abbreviation	Applies to PJ	Description
Health Insurance Act	Zvw	Yes	Main health care regulation regarding quality, organization and funding. Oversight and control assigned to the Dutch Healthcare Authority (NZa)
Youth Act	Jw	Yes	Main regulation regarding youth including mental health care quality, organization and funding. Oversight and control assigned to municipalities. Oversight and control assigned to Inspection Healthcare and Youth (IGJ).
Social Support Act	Wmo	No	Dictates municipalities how to organize various services including very limited mental health care .
Chronic Care Act	Wlz	No	Regulation of care for patients admitted longer than 1095 days.
Forensic Care Act	Fzw	No	Regulation of care mandated by judges, etc.
Healthcare Quality, Complaints and Disputes Act	WGGKZ	Yes	Securing patient rights, setting requirements for dealing with complaints and disputes, safeguarding care quality.

The primary acts that apply to Pro Juventus are the JW for patients younger than 18 years old and the ZVW for patients 18 years or older. When a patient turns 18 during treatment, they are transitioned into the ZVW system. Special regulation applies to these cases.

Pro Juventus does not provide care financed through the other acts. The WMO dictates how municipalities should organize various services, including a very limited selection of mental health care such as preventing loneliness. The WLZ covers patients admitted for longer than 1095 days. The FZW covers patients that undergo mandatory treatment, for example as part of a court ruling. Pro Juventus is also affected by the Healthcare Quality, Complaints and Disputes Act (WKKGZ). This act manages healthcare quality and secures patient rights about complaints and receiving information.

2.2 Organization structure

Pro Juventus operates clinics in Kampen, Ommen, Wezep and Wijhe. The clinic in Ommen was opened during this research. The owner holds all real estate in a separate holding called Graveland B.V. Staff can be grouped in three categories: management, practitioners, and supporting staff. Practitioners are grouped in multidisciplinary teams headed by a coordinator.

2.3 Care at Pro Juventus

The primary process of Pro Juventus is providing mental health care. This section classifies the types of care offered by Pro Juventus.

2.3.1 Types of care

Care by Pro Juventus can be grouped as below:

1. Youth: patients younger than 18 years old, financed by municipalities.
2. Adults: patients of 18 years or older, financed by health insurers.
    a. Basic mental health care
    b. Specialized mental health care
3. Express: private care for any individual, financed by the clients.

Group 1 and 2 include nearly all provided care. Group 3 is an extremely small number of appointments and its discontinuation is being considered. Patients move from youth to adult care if they become 18 years old before their discharge as described in Section 2.1. 45% of practitioner FTE is estimated to be spent on adult care and 55% on youth in 2017 (Pro Juventus, 2017).

Youth

Municipalities cooperate in youth regions. The responsible youth region assigns a profile to youth patients indicating the expected treatment intensity and associated budget. Youth regions have their own processes and profiles. Profiles can be result-based or product-based. Result based profiles provide a fixed budget and require predetermined results to be achieved. Product based profiles mean treatment is cancelled when the budget has been fully utilized. Pro Juventus cooperates with youth regions *IJsselland*, *Midden IJssel* and *Noord Veluwe*. Table 3 lists some statistics about youth care at Pro Juventus.

Table 3 – Youth care at Pro Juventus in 2017 (Pro Juventus, 2017)

	Unique youth patients
Open care paths on January 1st	1296
Opened care paths during the year	213
Closed care paths during the year	348
Open care paths on December 31st	1161

Adults

Adult patients are split over general basic mental health care (GB-GGZ) and specialized mental health care (G-GGZ). The general practitioner referring the patient makes the primary assessment, which Pro Juventus verifies during the intake.

GB-GGZ patients are assigned one of four categories based on regulatory profiles (Nederlandse Zorgautoriteit, 2018). These profiles describe factors such as risk, complexity and impact on daily functioning by the related complaints. The categories and their codes in ascending order of severity are:

1. GB-GGZ Short BK
2. GB-GGZ BM
3. GB-GGZ Intensive BI
4. GB-GGZ Chronic BC

G-GGZ patients are treated based on a DSM-5 diagnosis (Nederlandse Zorgautoriteit, 2017). G-GGZ care is funded through standardized units called a DBC, short for 'diagnosis and treatment combination'.

Table 4 shows that most adult care paths are G-GGZ. (Note that a patient could move between care paths or have parallel care paths.)

Table 4 – Adult care at Pro Juventus in 2017 (Pro Juventus, 2017)

	GB-GGZ care paths	G-GGZ care paths	Unique adult patients
Open care paths on January 1st	75	513	498
Opened care paths during the year	85	649	385
Closed care paths during the year	99	561	319
Open paths on December 31st	61	601	564

Express

Express patients are usually one-off tests such as IQ tests. Express patients can be of any age. Express care consisted of minimal numbers of patients per year. Pro Juventus is considering discontinuing Express care. These factors combined place it outside the scope of this research.

2.3.2 Types of practitioners

Not every practitioner can provide all types of care. For example, a psychologist cannot prescribe medication while a doctor or psychiatrist can. Additionally, only certain practitioners can be the main practitioner for a patient. The main practitioner is responsible for the coordination and continuity of a patient's care path.

2.4 Stakeholders of Pro Juventus

This section describes stakeholders of changing operations management at Pro Juventus. Stakeholders are scored on three dimensions listed below. Each stakeholder is classified as major or minor based on their scores. Scores are based on conversations with various staff members. Scores are summarized in Table 5 at the end of this section. The management team is the decision maker and therefore not included in this overview.

- Power: how much influence does the stakeholder have on changes at Pro Juventus?
  - Scored high, medium or low
- Interest: how much do changes matter to the stakeholder?
  - Scored high, medium or low
- Attitude: is the stakeholder supportive or resistant to changes at Pro Juventus?
  - Scored ally, neutral, or opponent

2.4.1 Patients and their families

Patients are often referred to Pro Juventus by general practitioners or their municipality's youth care. Patients are unlikely to change care providers because all care providers have long waiting lists. These things combined give patients low power. Patients are interested in tangible aspects of their care (Detsky, 2011): waiting times, their recovery, scheduling, facilities, and so on. However, the operations management is abstract and invisible to them. Patients are unlikely to notice changes because they only see their own interactions with the organization: they do not see a "before and after" comparison. However, better care leads to better experiences and reviews. This leads to medium interest. Patients are unaware that changes might be made, nor is it relevant to them at an individual level. This makes them neutral to such changes. Patients and their families are a minor stakeholder.

2.4.2 Health insurers

Health insurers finance care for adult patients. Pro Juventus does not have contracts with health insurers, so the insurers must pay standardized rates as mandated by the health care act. Health insurers sometimes require all bills to be sent by the patient instead of the clinic, which causes some bills not to be paid. Health insurers have various legal rights to combat fraud. These tools can also be used to pressure Pro Juventus. This legal framework means health insurers have high power. Health insurers have medium interest: they are not interested in internal processes of individual care providers, as long as they don't incur extra costs. The mutual responsibilities are defined in the health care act, and how these are met are not important. Health insurers care about clear communication, correct billing and similar details. Health insurers are neutral to changes. So long as obligations are met and they get the information they need in a timely manner, everything else is of little concern. Health insurers are a minor stakeholder.

2.4.3 Municipalities and youth regions

Municipalities are responsible for organizing mental health care for youth. They cooperate in youth regions to fulfill this task. The youth regions purchase care for their patients. The shortage of mental health care prevents them from easily switching between care providers. These factors balance each other out, giving municipalities medium power. Because youth regions have insufficient budget (Trouw, 2017) , they value effective care. The cheaper patients can be sufficiently treated, the more people they can help. This makes them very interested in the results and flexibility of mental health care providers, but details such as internal processes at care providers are only a distraction. This gives them medium interest as well as a neutral attitude. Municipalities and youth regions are a minor stakeholder.

2.4.4 Practitioners

Practitioners are necessary to provide care. The shortage of practitioners in the Dutch mental health care sector gives them a solid negotiating position relative to their employers. Practitioners are interested in how changes could affect their own work and benefit patients. However, operations management is abstract to them requires a higher-level overview than they have. This leads to medium interest. Practitioners are support or resist change depending on the implications. Changes that impact how they do their work will be resisted, while changes reducing administrative work would be supported. Practitioners are a major stakeholder.

2.4.5 Owner

The owner is Ronald Graveland. He returned to the management team during this research. He owns all real estate in a separate holding. He is also a psychiatrist, which are in high demand in the mental health care sector. This gives the owner high power. Mr. Graveland is very involved in the organization. The organization is his business in a financial sense, which is important to him. He prefers providing care over running the organization but considers the latter as necessary. This gives the owner high interest. Mr. Graveland has a positive attitude towards change. The owner is a major stakeholder.

2.4.6 Supporting staff

The supporting staff has few ways to affect decision making. Their position is not strengthened by shortages like with the practitioners. They do not feel represented by the staff representation. Their main option is to discuss their concerns with the operations manager. This gives them low power. The supporting staff has a high interest because they believe changes are likely to affect their work. They have a high-level overview which leads to frustrations when things they had warned for go wrong, and changes in operations management could affect those frustrations. They also care deeply about the organization. Supporting staff welcome change, provided they believe it is in the best interest of the organization. However, they believe they do not have time for extra work. Supporting staff is an ally or opponent depending on their own views on the effectivity of the intervention. Supporting staff is a major stakeholder.

2.4.7 Stakeholder overview

Table 5 presents an overview of all stakeholders and their scores when changing operations management at Pro Juventus.

Table 5 – Stakeholder overview

Stakeholder	Power	Interest	Attitude	Type
Patients and families	Low	Medium	Neutral	Minor
Health Insurers	High	Medium	Neutral	Major
Municipalities and youth regions	Medium	Medium	Neutral	Minor
Practitioners	High	Medium	*Varies*	Major
Owner	High	High	Ally	Major
Supporting Staff	Low	High	*Varies*	Major

2.5 Contents and limitations of electronic health records

During treatment some standardized data is collected in the electronic health records. This section describes the collected data and its limitations.

2.5.1 Primary contents

The most important contents are the tables of “treatments”, patient details, and appointment details.

The treatments table records reflect a profile in case of youth and a DBC in case of adults. These tables primarily contain data such as patient IDs, start and end dates, main practitioner and whether the treatment is still ongoing. Appointment records contain details about consultations, group sessions and phone contact. Patient data includes dates of birth, whether they are on the waiting list and health insurer information.

2.5.2 Data quality limitations

There are several factors that negatively impact the data quality of the electronic health records.

Care path representation

Care paths are not easily identifiable in the electronic health records. For youth one profile is represented as one “treatment”. For adult care each DBC is registered as its own “treatment”. This creates multiple entries for one care path if treatment takes longer than a year, if a patient receives a new diagnosis, if a patient transitions from GB-GGZ to G-GGZ or vice versa, or if a patient transitioned from DSM-IV to DSM-5 diagnosis. All these situations require a new DBC to be opened.

Diagnosis registration
G-GGZ diagnoses are registered according to DSM-IV classifications up until DSM-5 was introduced at 1-1-2018. A conversion table is provided by the NZa to convert DSM-5 into DSM-IV (Nederlandse Zorgauthoriteit). Transformation the other way around is not possible, because DSM5 has a higher level of detail (Nederlandse Zorgautoriteit, 2017).

Regulatory changes
Regulatory changes in 2015 changed a lot of rules about which data should be recorded and how. This makes all data prior to 2015 difficult to compare with newer data. Since 2015 small changes have occurred, primarily regarding youth care. DBCs are no longer used for youth care since 2018. Other changes are minor.

GAF score
GAF is an acronym for *Global Assessment of Functioning*. It's a score between 0 and 100 where higher scores represent better functioning. GAF scores should be recorded at intake and discharge. However, when looking at all closed care paths started since 2015, GAF scores are not updated in a disproportionate number of cases (6075 out of 8192). It's uncertain whether this is a registration. This makes the GAF score at discharge unreliable for analysis.

Missing youth profiles
Youth profiles are not reflected properly for new care paths. Profiles are not visible in the records if time spent by practitioners is not registered for the treatment.

Incorrect cancelation registration
Some staff mentioned appointments cancelled by patients were often registered incorrectly in the past. Patients cancelling within 24 hours of the appointment should be billed, but these were sometimes registered as being cancelled earlier. More recent data should be more accurate, but there is no clear boundary where the data becomes reliable.

Open DBCs not yet validated
In the DBC system, data gets validated when the DBC is closed. The information system performs a technical validation, checking if all data seems correct, after which the main practitioner must approve the data. This means data for all open DBCs is not yet validated.

Group sessions in appointments table
Group sessions in the appointment table are represented by a separate record per patient. Basic operations such as summing time spent by a practitioner require an extra filter to prevent counting one appointment multiple times.

One practitioner per appointment
Only one practitioner can be linked to each record in the appointment table. Just like patients in group sessions, there is a record per practitioner present. This means that when looking at patient appointments, duplicate intake appointments should be removed.

Test data present
In the electronic health records, several dummy patients and appointments exist. These must be filtered out during any analysis to prevent distorting the results.

Incorrect data typing
Not all data types are recognized correctly after being exported from the database. This requires extra care when working with the data. For example, sorting dates only works if the values are interpreted correctly.

2.5.3 Other limitations

No link with HR systems

Because there is no direct link with the HR systems, certain types of analytics require manual data aggregation. This complicates such processes. HR can provide tables of staff and their respective start and departure dates, but there's no link between practitioner IDs in the exported electronic health care records and the lists provided by HR.

2.6 Conclusions

Pro Juventus operates in relatively simple domains of mental health care by limiting itself to outpatient care and not offering chronic or forensic care. Clinics are in Kampen, Ommen, Wezep and Wijhe. As mentioned under *Types of care* in Section 2.3, 45% of practitioner FTE is estimated to be spent on adult care and 55% on youth care in 2017. There are roughly twice as many unique youth patients as adult patients in 2017. Adult care is split in general (GB-GGZ) and specialized (G-GGZ) mental health care. There are roughly 7 specialized adult care paths per general adult care path in 2017. The most important stakeholders of Pro Juventus are health insurers, practitioners, supporting staff and the owner. The quality of automatically collected data is low, primarily because of inhomogeneous data and incorrect registration.

3 Operational performance

This chapter answers Research Question II: "What is the operational performance of Pro Juventus?" by answering the related sub questions in the sections described in Table 6, before concluding the chapter in Section 3.4.

Table 6 – Section numbers per sub question of Research Question II

Section	Sub question
3.1	A. How does Pro Juventus currently measure its performance?
3.2	B. Which information does management think they need?
3.3	C. What is the current workload per type of care?

3.1 Current performance

This section describes the current performance of Pro Juventus. Pro Juventus uses these performance indicators:

1. Financial performance
2. Practitioner productivity (billable hours)
3. Patient satisfaction
4. Pre-intake waiting times

3.1.1 Financial performance

Financial performance is an important metric. Pro Juventus is currently operating at a net loss. Investments towards growth such as the new clinic in Ommen and the practitioner productivity discussed below explain this loss.

Table 7 – Financial performance of Pro Juventus (CIBG, 2019)

	2014	2015	2016	2017	2018 (preliminary)
*Revenue * €1000*	4.356	4.363	4.998	5.191	5.300
*Net result * €1000*	627	-64	209	132	-30

3.1.2 Practitioner productivity

The practitioner productivity is defined as the percentage of their working hours that can be billed. The average productivity from January 2019 up to and including July 2019 is 61%. Management considers 75% the required minimum. Management is actively working on monitoring and increasing productivity, because they believe this is the biggest factor towards improving the organization's financials.

3.1.3 Patient satisfaction

Patient satisfaction is tracked internally. Ratings are processed on a quarterly basis. Surveys are sent out 200 days after the start of a care path. If the patient is less than 18 years old, their parents are also invited to the survey. If the patient is less than 11 years old, only their parents are invited.

Response rate in the first quarter of 2019 is 25,9% (30 out of 116) with an average grade of 8.1 on a 1-10 scale. One patient gave Pro Juventus an insufficient grade. Staff is looking for ways to increase response rate. It is currently up from 10% 2017 by sending the survey earlier and using a digital platform instead of paper questionnaires.

Patients placed only few ratings on the Dutch care map in the last four years (Patiëntenfederatie Nederland), though average ratings are very high. Table 8 shows this data. Pro Juventus does not encourage patients to leave ratings here. Pro Juventus does not use the ratings from the Dutch care map, favoring its internal tracking instead.

Table 8 – Patient ratings by year on the Dutch care map

Year	Average rating	Number of ratings
2018	9.2	6
2017	9.4	11
2016	9.0	13
2015	9.4	12
2014	9.0	34

3.1.4 Pre-intake waiting times

Pro Juventus has fixed slots for patient intake appointments at each of their clinics. The pre-intake waiting time is defined as the time before a clinic's first free intake slot. The waiting time is measured separately for each location as well as the distinction between youth, GB-GGZ and G-GGZ. Table 9 shows the current pre-intake waiting times per Pro Juventus clinic.

Table 9 – Pre-intake waiting times per location in weeks

Type of care	Wezep	Wijhe	Kampen	Ommen	Last updated
Youth	4	12	12	10	18-6-2019
Adult (GB-GGZ)	7	6	6	12	25-6-2019
Adult (G-GGZ)	7	6	8	12	25-6-2019

Differences in waiting times for different types of care at the same clinic are a result of the fixed intake slots, which are pre-allocated to a specific type of care. Differences between clinics for the same type of care are a result of the weekly number of intake slots and the number of patients currently on the waiting list.

3.2 Desired information

This section answers sub question B: *"Which information does management think they need?"*

Pro Juventus wants to maintain a mix of complex and simple active care paths. This requires predictions on care complexity for new patients. Management believes patterns from the electronic health records could provide the required information. They consider multidisciplinary meetings regarding a care path and the number of appointments per unit of time to be indicators of complex care. Management is interested to see if there are similarities between patients with the same diagnosis.

The owner is also interested in ways of being more deliberate on which patients to take in. He indicates that by prioritizing patients with complaints that match expertise available at Pro Juventus, patients can have a better experience and the organization can provide care more effectively. He would also like to factor in the urgency of a patient's complaints to prioritize their treatment, instead of the current *"First Come, First Serve"* approach.

Finally, Pro Juventus is interested in any other information retrieved from the electronic health records in a general sense. The electronic health records are a proverbial haystack with an unknown number of needles.

3.3 Workload per type of care

This section first provides a workload definition, followed by an interpretation of the results.

3.3.1 Workload definition

The number of unique patients, appointments, registered administrative tasks, the number of multidisciplinary meetings, and the number of no-shows are counted during the second half of 2018. Statistics are collected separately for youth, GB-GGZ and G-GGZ. Ratios are determined per type of care. This definition is established in accordance with the director of Pro Juventus.

3.3.2 Data processing

Appointment records were processed in R. Appointments were filtered based on date and test data was removed. Appointments were linked to the correct type of care based on patient IDs. Statistics were collected per type of care and summed for the total values afterwards. Finally, the ratios were calculated.

3.3.3 Results

Table 10 shows statistics for each type of care at Pro Juventus. The percentages are relative to each row. Table 11 shows ratios based on the statistics from Table 10 as indicators of workload per type of care.

Table 10 – Workload statistics per type of care in second half of 2018

	Youth		GB-GGZ		G-GGZ		Total	
Statistic	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Unique patients	1.197	40%	319	11%	1.481	49%	2.997	100%
Appointments	11.722	22%	3.109	6%	38.730	72%	53.561	100%
Administrative tasks	962	24%	233	6%	2.830	70%	4.025	100%
MDOs	1.008	22%	333	7%	3.259	71%	4.600	100%
No-shows	95	18%	34	6%	410	76%	539	100%

Table 11 – Ratios per type of care in second half of 2018

Ratio	Youth	GB-GGZ	G-GGZ	Total
Appointments per unique patient	9,8	9,7	26,2	17,9
Appointments per administrative task	12,2	13,3	13,7	13,3
MDOs per unique patient	0,8	1,0	2,2	1,5
No-shows as percentage of appointments	0,8%	1,1%	1,1%	1,0%

The results indicate that on average youth patients and GB-GGZ patients have much fewer appointments than G-GGZ patients. G-GGZ patients also seem to require double the number of multidisciplinary meetings (MDOs). The workload from youth and GB-GGZ patients seems to be very similar per patient, while G-GGZ cases seem a lot more intensive. Finally, we see the number of patients has grown immensely from the numbers in the 2017 annual report that were presented in Section 2.3. which showed similar numbers of youth patients but roughly a quarter of the adult patients. There are many more G-GGZ patients than management was aware of before this research.

3.4 Conclusions

Pro Juventus has seen consistent growth in revenue since 2015. Net results have fluctuated because of investments towards growth and low practitioner productivity. Average productivity is 61% in the period of January 2019 up to and including July 2019, while management believes 75% is required. Management is actively working on improving practitioner productivity. Patient satisfaction is relatively high at an average score of 8,1, but the response rate to the satisfaction survey is low at 25,9%. Only few ratings are placed on the Dutch care map, but those that are placed are also high. Waiting times at Pro Juventus vary per location and type of care between 4 and 12 weeks. Differences are caused by the fixed number of weekly intake slots at each clinic and the respective number of patients on each waiting list.

As shown in Table 10, 49% of all patients in the second half of 2018 are G-GGZ patients. This is much higher than management was aware of. 72% of appointments in the second half of 2018 were for G-GGZ patients. These patients also require more double the multidisciplinary meetings than youth and GB-GGZ patients do. The proportion of administrative tasks and no-shows seem similar for all types of care. Youth patients and GB-GGZ patients have similar ratios for the chosen workload indicators in Table 11.

4 Literature study

This chapter answers Research Question III: "What does literature say about operations management in mental health care?". Section 4.1 explains how little literature currently exists and which other topics have been consulted for relevant articles. Section 4.2 lists results from the collected literature. Finally, section 4.3 covers the sub question *"Which KPIs should be monitored during a patient's treatment to improve discharge prediction accuracy?"* Section 4.4 summarizes the conclusions of this chapter.

4.1 Literature availability

Appendix 8 lists queries initially used to search for relevant literature. The appendix shows how very broad queries in two major databases come up with very few results. The relevant articles cover a limited range of topics, too narrow for a full literature review. This motivated a search for literature on other topics that could be applied to the situation at Pro Juventus.

Appendix 8.2 clarifies the brainstorm used to determine other topics. The results and motivations are:

- Analytics of "electronic health records".
    - Electronic Health Records in all health care sectors share many similarities because of how health care is regulated. This research is not limited to the mental health sector because of this.
- (Big data) analytics in general.
    - The large amount of records at Pro Juventus could be approached as a big data project. Information from big data analytics can provide relevant tools and knowledge.
- Operations management at dentists, physical therapists, general practitioners, outpatient clinics and medical rehabilitation centers:
    - At a foundational level, care at all these providers is like at Pro Juventus: patients arrive by appointment, have their session, and leave.
        - The patient intake at Pro Juventus is a step missing at these other providers.
    - Especially the dentists and physical therapists feature a lot of recurring appointments just like Pro Juventus, though dentists see their patients at a much lower frequency.
        - A dentist never "discharges" patients, which is like patients that indefinitely need medicine.
    - Physical therapists and medical rehabilitation also provide group sessions, like at Pro Juventus.
        - The other examples do not provide group sessions.
    - Care complexity varies a lot between these examples
        - The dentist and physical therapy see much lower complexity compared to Pro Juventus.
        - Then general practitioner and outpatient clinic see similar complexity as at Pro Juventus.
    - General practitioners tend to have a lot of one-off appointments instead of longer care paths with recurring appointments.

These other topics did not result in papers that could be applied to the case at Pro Juventus.

4.2 Literature study results

This section describes the conclusions drawn from consulted literature about the subjects from section 4.1.

4.2.1 Taxonomic Classification of Pro Juventus

In the framework of *Taxonomic classification of planning decisions in health care* (Hulshof, Kortbeek, Boucherie, Hans, & Bakker, 2017), Pro Juventus would be classified as ambulatory care service. They write that the main strategic decisions are regional coverage and service mix. For coverage, the trade-off is between accessibility and efficiency. Pro Juventus has various clinics spread over its service area. Service mix defines which types of treatment are offered. As mentioned in Section 2.1, Pro Juventus offers youth care, general mental health care and specialized mental health care, but not forensic, crisis or inpatient care. This simplifies the resources required for Pro Juventus to operate as they do not have to house or feed patients, and all patients arrive by appointment.

In the same review, patient routing is mentioned as a tactical component. Patient routing involves how a patient move through several stages of care, such as consultation, diagnostics, and another consultation. This does not apply to Pro Juventus, as patients generally have only one stage of treatment each day they visit. Another tactical attribute is the organization's access policy. Access to practitioners on the day of an appointment is based on one queue per practitioner. There is no possibility of walk-in patients as there is no crisis care. With the current scheduling system, practitioners have time allocated for administrative tasks directly following the related appointment. Admission control is a third tactical component, related to how new patients are selected for treatment. Pro Juventus utilizes a "first come, first serve" doctrine for its waiting lists, as stated in Section 1.3.

Patient-to-appointment assignment is defined as an offline operational aspect. For Pro Juventus, patients can any number of appointments at once based on their preference and practitioner availability. In case of group sessions, predetermined options limit the patient's potential choices.

Pro Juventus does not do dynamic patient reassignment, which is considered as online operational planning by Hulshof *et al*'s framework. The only exception is practitioner sick days, where patients are sometimes offered another available practitioner as alternative to rescheduling.

4.2.2 Data driven operations management

Various books and papers recommend applying data driven analytics to health care operations management ([Ward, Marsolo, & Froehle, 2014], [Denton, 2013], [Pierskalla & Brailer, 1994]). Provided examples are demand forecasting, location selection, capacity planning, outpatient scheduling and clinical decision making. (Wang, Kung, Wang, & Cegielski, 2018)

Big data analytics can assist in predicting no-shows (Ma, Seemanta, Wu, & Ng, 2014), improving process control, lowering costs and improving resource utilization (Mehta & Pandit, 2018), but that evidence for achieving these benefits is limited. In most of these cases, electronic health records are used as one of many data sources.

Levels of analytics

Literature defines various levels of data analytics (Davenport & Harris, 2007). These levels can be classified as descriptive, predictive and prescriptive (Saggi & Jain, 2018). Descriptive analytics displays aggregated historic data. Predictive analytics tries to describe the future. Prescriptive analytics recommends decisions. Each class requires analytics from the class below it. For example, to make forecasts from the predictive category, data from the descriptive stage is required. The levels and classes are visualized in Figure 2 – Levels of data analysis (Watson, 2012).

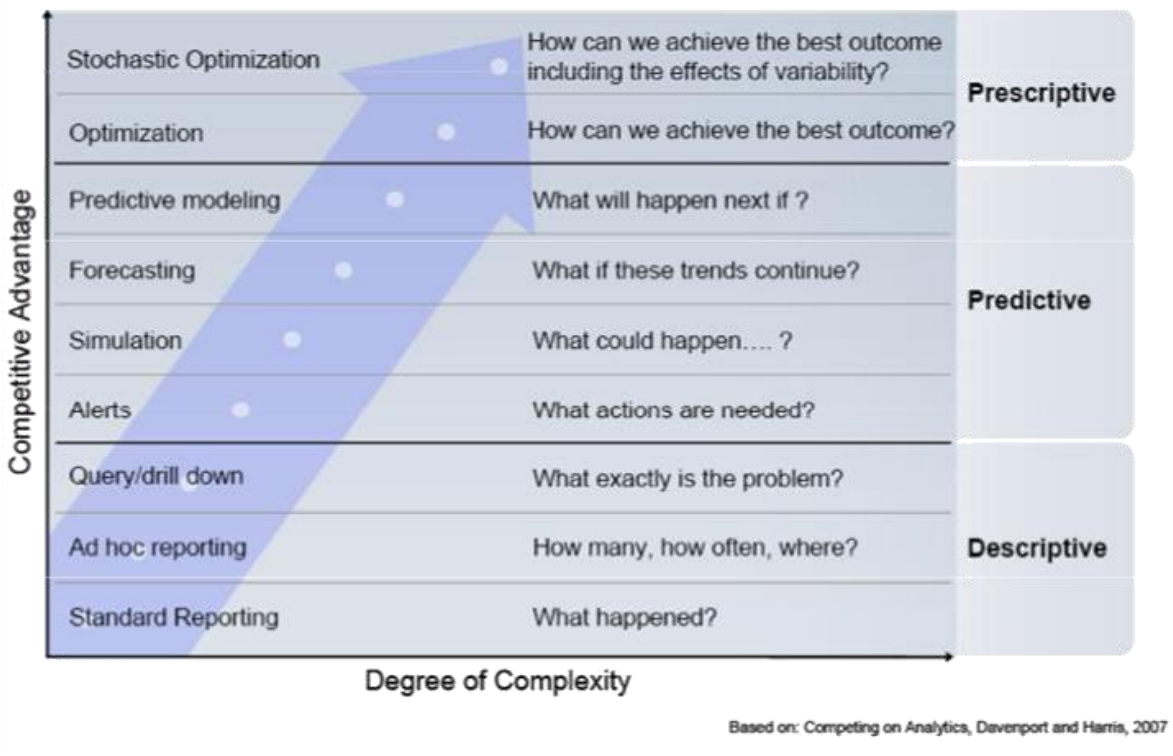


Figure 2 – Levels of data analysis

Stages of analytics

Literature recommends splitting analytics into various stages ([Wang, Kung, & Byrd, 2015], [Saggi & Jain, 2018]). The suggested process consists of sequentially capturing, transforming, analyzing and consuming data.

The capture stage is all about data collection and immediate storage. No processing is done. For example, tracking the electronic health records. The transformation stage involves cleaning up the raw data and preparing it for analytics. This stage can also be used to combine data from various sources, for example the electronic health records and HR data. The analytics stage is where the actual analytics are performed, for example through statistical tests. The consumption stage provides the results from the analytics in a format for human consumption, such as a dashboard or report.

Limiting factors of analytics

Research warns not to overestimate the value of electronic health records ([Ward, Marsolo, & Froehle, 2014], [Tse & You, 2011]). Electronic health records often allow the same information to be tracked in different ways. Therefore, these records they lack the consistency required for analytics. A provided example is a diagnosis that could appear in a problem list or their full medical history. Standardization of input can benefit the data quality and therefore analytics value.

Correct interpretation of the results is important. Research warns for incorrect interpretation leading to "errors and questionable decisions" (Wang, Kung, Wang, & Cegielski, 2018). Training in critical thinking and basic statistics is recommended to the staff that interprets the data as preventative measure.

4.3 Predicting discharges according to the literature

This section discusses research question *"Which KPIs should be monitored during a patient's treatment to improve discharge prediction accuracy?"*

Little research exists about predicting patient discharges in mental health care. One review explores discharge planning from in-patient to out-patient treatment, but it covers few trials and a different context (Steffen, Kösters, Becker, & Puschner, 2009). It cannot be generalized to Pro Juventus.

One review evaluated the concept of discharge planning in mental health care (Xiao, Tourangeau, Widger, & Berta, 2019). However, articles included in this review revolved around patients transitioning from inpatient to outpatient care. Additionally, included articles focused on how to assist patients and how to organize the process, instead of predicting when patients would be ready to end their treatment completely.

Another paper was able to predict same-day discharges following a specific surgical procedure (El-Sharkawy, Tewari, & Vohra, 2019). The model was based on a regression analysis of data such as age, sex, preoperative investigations and primary surgery indication. However, this type of treatment is not comparable with the mental outpatient care at Pro Juventus, and the decision is a binary one instead of guessing a point on a timeline.

KPIs for predicting a patient's discharge could be determined by conducting interviews with practitioners about how they currently asses treatment progress, as their decision process is the main cause for patient discharges. The results from these interviews could be used as a starting point for exploratory data analysis as explained in Section 6.4, or as indication of which new data should be collected and evaluated.

4.4 Conclusions

This section summarizes the conclusions from the literature result and relates them to Pro Juventus.

Applying data driven operations management to health care processes is recommended. Examples are outpatient scheduling, clinical decision making, predicting no-shows, process control and improved resource utilization. However, evidence for these benefits is limited. Electronic health records are often used a source of data.

Data analysis requires numerous stages. Data should be collecting, preparing, analyzing and consuming data. Research warns not to overestimate the value of electronic health records because data often lacks consistency.

There is a limited amount of literature available regarding operations management in mental health care. Literature about operations management at other care providers usually revolves around appointment strategies and productivity. No research focused on predicting discharges was found that was applicable to the situation at Pro Juventus.

5 Workload per initial primary diagnosis

This chapter answers Research Question IV: *"To what extent do patients with the same initial primary diagnosis place the same workload on the organization?"* Section 5.1 describes the applied methodology. Section 5.2 presents and interprets the results. Section 5.3 provides the conclusions to the research question.

5.1 Methodology

This section describes how the workload is defined, which data was included in the analysis and how the data was processed.

5.1.1 Workload definition

The number of appointments, the number of registered administrative tasks and the number of multidisciplinary meetings about a patient are considered with respect to time. The number of no-shows is tracked as fraction of total appointments. The number of days from start to end of treatment is tracked as final indicator. This definition is established in accordance with the problem owner.

5.1.2 Data selection

Table 12 shows the selection criteria and remaining population. Less than 10% of data remained after selection. Available data of all patients was filtered to only include adult G-GGZ patients who entered treatment since 1-1-2015 whose treatment has finished. Older data is difficult to compare because of changes in legislation. Youth and GB-GGZ patients are excluded because the registered treatments do not include a diagnosis, as well as changes to youth care over this period described in Section 2.5. Youth patients who transitioned into adult care are included based on their first adult diagnosis to have more data points. Appointments not linked to a patient were omitted, such as travel time between clinics. Patients with only registered 1 appointment were omitted as outliers. This resulted in a population sample of 503 patients. DSM-5 diagnoses were converted to DSM-IV counterparts using the NZa's conversion table before grouping patients per diagnosis. This resulted in 64 groups. Diagnoses with fewer than 8 patients were omitted because of their small sample size. This resulted in 17 diagnoses covering 396 patients to compare to the total population.

Table 12 – Data selection criteria and remaining population

Criterion	**Remaining patients**	**Mutation**
Entire dataset	5870	
Finished treatment	2805	-3065
Adult patients	1059	-1746
In treatment since 1-1-2015 or later	573	-486
Recorded diagnosis	520	-53
More than 1 appointment	503	-17
Primary diagnosis with at least 8 patients	396	-107

5.1.3 Data processing

Records were processed in R. Statistics were collected for all patients. Spearman's correlation coefficients were calculated for indicators of the workload definition in the entire population. Finally, the indicators from the workload definition are determined and evaluated per diagnosis and compared to the total population.

5.2 Results

This section first describes some characteristics of the entire population, followed by discussion of the indicator means and confidence interval per diagnosis. Numerical output used for graphs in this section is available in Appendix 8.3. The table in the appendix also contains the diagnosis names per numbered index.

5.2.1 Population characteristics

Figure 3 shows the correlation coefficients for patient attributes in the entire population. Length of Stay (LoS) is positively correlated with more time appointments. This is expected. The time between appointments has a weak correlation with LoS and administrative tasks per day. This is consistent with the problem owner's assumption that some patients stay in treatment very long because of routine medicine checks, without receiving treatment. These cases also require little administration. There is no significant correlation between any other pair of indicators, as all other values sit near zero. This implies these attributes are statistically independent characteristics.

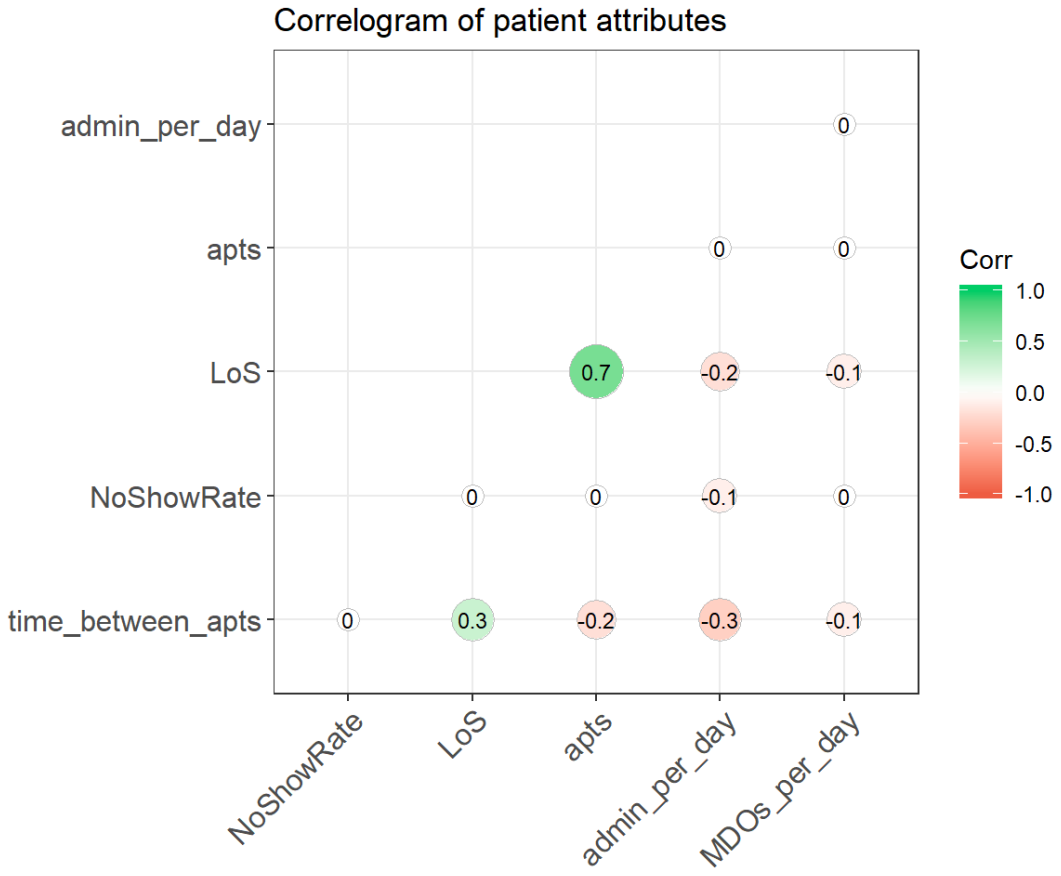


Figure 3 – Correlogram of patient statistics

5.2.2 Days between appointments

Figure 4 shows the 95% confidence interval for the mean number of days between appointments per diagnosis. The blue area represents the confidence interval for the mean of the entire population.

The results show all included diagnoses as well as the population overlapping each other. This indicates there is no statistically significant difference in the time between appointments when comparing diagnoses to the population or each other.

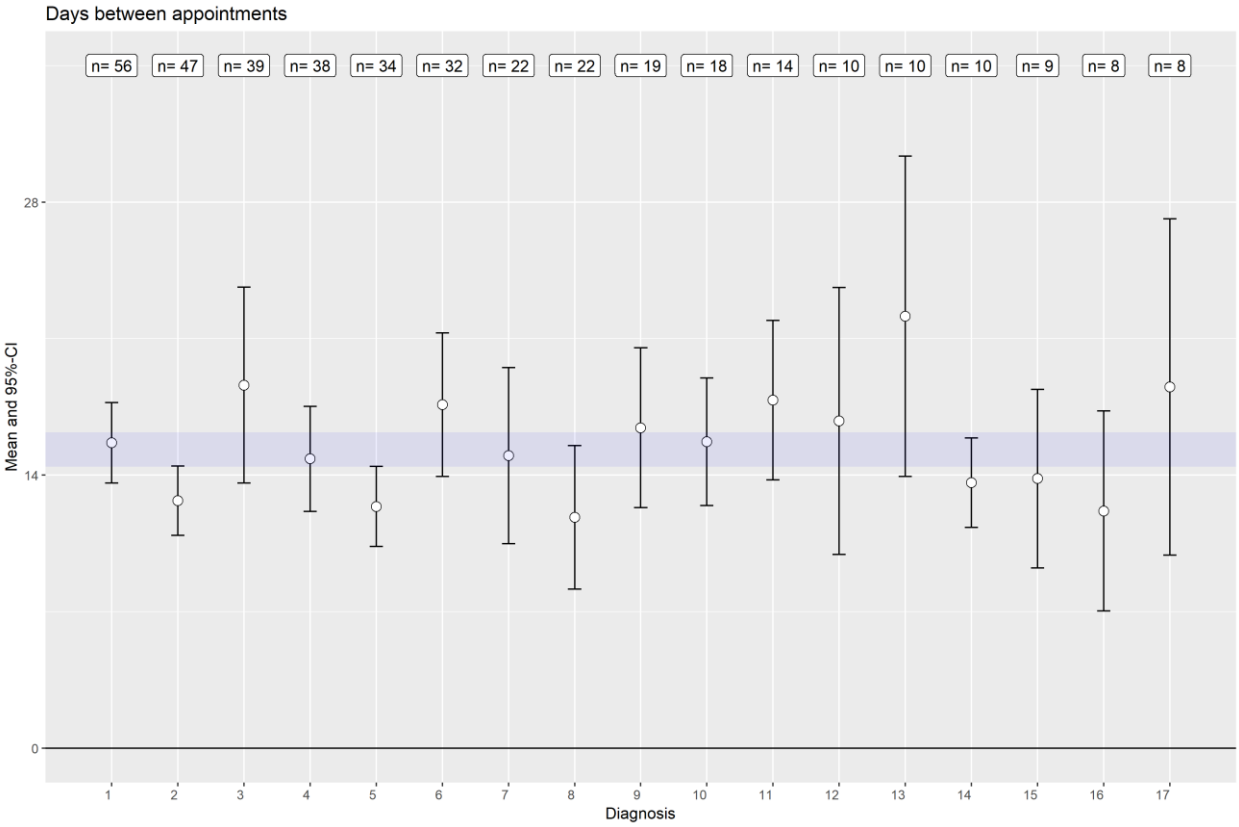


Figure 4 – Days between appointments per diagnosis

5.2.3 Administrative tasks

Figure 5 displays the number of registered administrative activities per day of treatment for each diagnosis. Reading case files, e-mailings and documenting sessions are considered administrative activities. The blue area represents the confidence interval for the mean of the entire population.

The results show unlikely low numbers. A mean of 0.01 would indicate one administrative activity per 100 days of a patient's treatment. The population mean confidence interval ranging from 0.009 to 0.12 implies incomplete registration of these activities. Assuming each diagnosis is equally affected by this, we do see some diagnoses with statistically significant differences. Diagnosis 4, 5, 7, 10, 12 and 16 are see significantly fewer administrative activities than the population mean and some other diagnoses. Diagnosis 8 is the only one seeing a significantly higher confidence interval than the population.

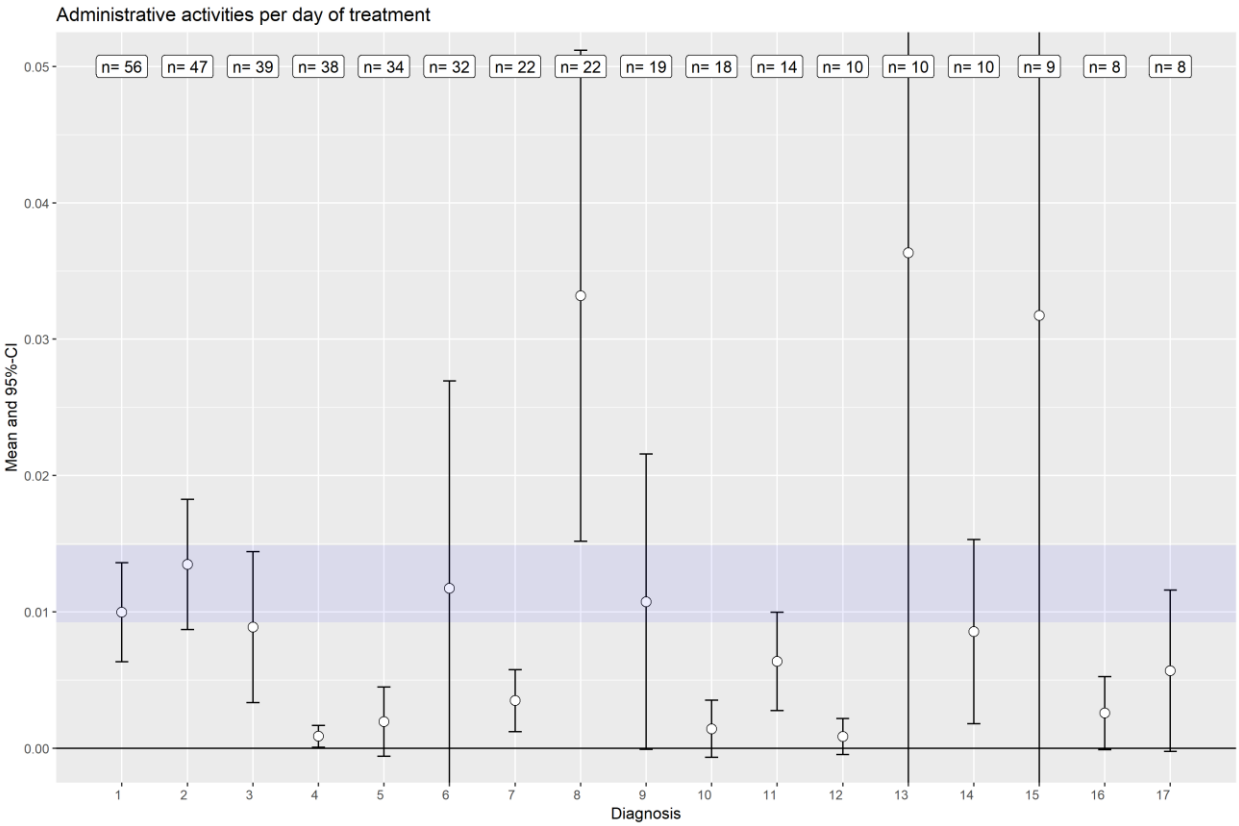


Figure 5 – Administrative activities per day of treatment

5.2.4 Multidisciplinary meetings

Figure 6 displays the number of multidisciplinary meetings (MDOs) per day of treatment for each diagnosis. The blue area represents the confidence interval for the mean of the entire population.

The confidence intervals for diagnosis 3, 7 and 12 are incredibly large compared to other diagnoses and the entire population. This indicates a widely varying complexity per patient for these diagnoses. Most other diagnoses are either fully or partially inside the population's confidence interval. This means there is no statistically significant difference for these diagnoses compared to the entire population. The only exception is diagnosis 4, which has statistically significantly fewer MDOs than the entire population as well as some other diagnoses.

5.2.5 No-show rate

Figure 7 shows the 95% confidence interval for the mean ratio of no-shows per diagnosis. The blue stripe represents the confidence interval for the mean of the entire population.

The results show relatively similar no-show rates for most diagnoses. Diagnosis 11, 16 and 17 are the only ones with a statistically significantly lower mean number of no-shows than the population average. Diagnosis 6 and 14 show a much larger variance than others. Because of the low sample size, these variances could be caused by outliers.

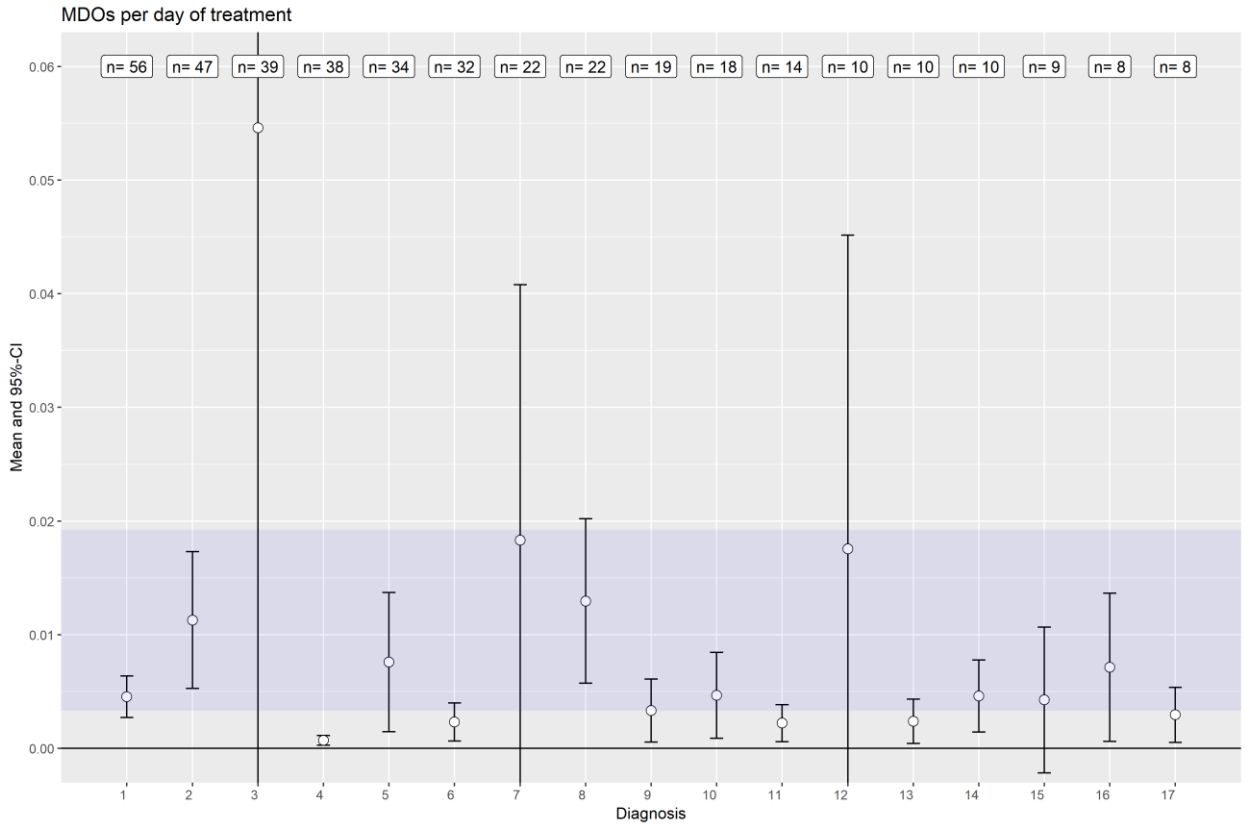


Figure 6 – Multidisciplinary meetings per day of treatment

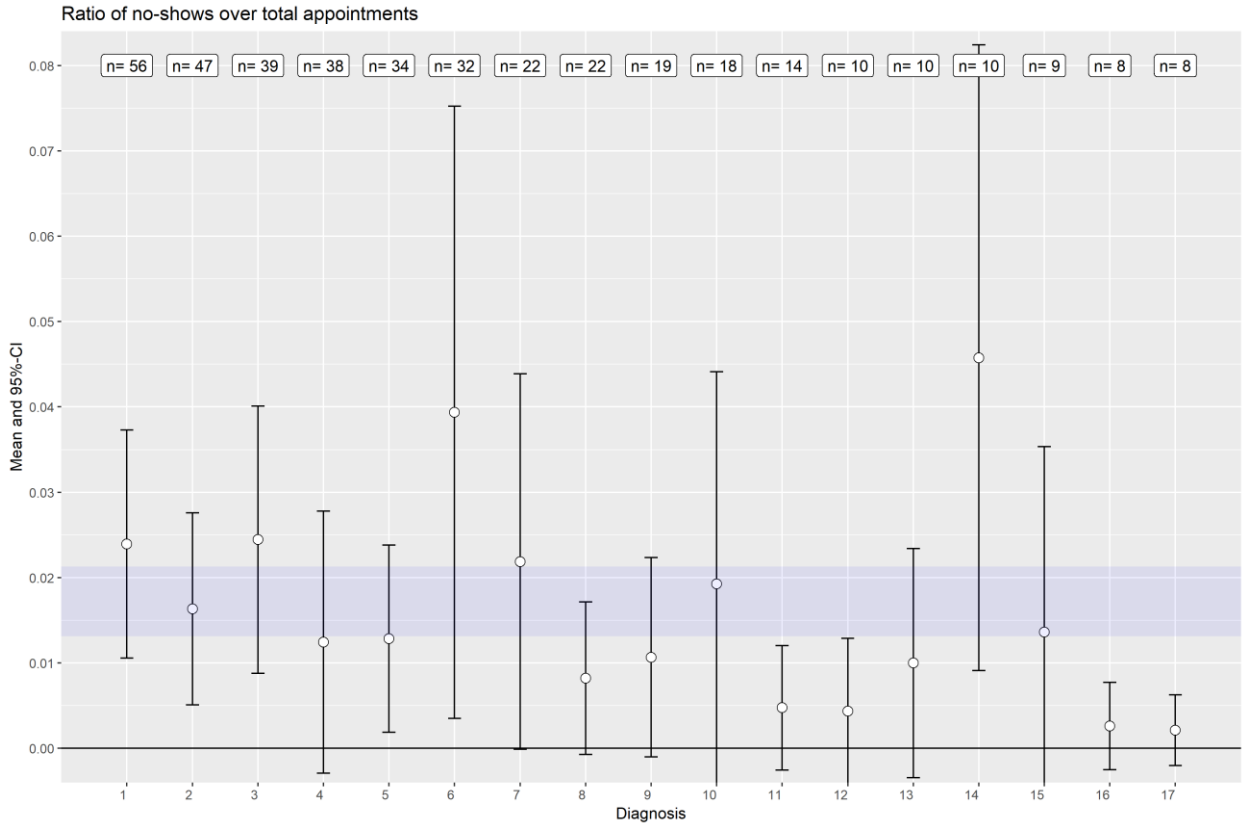


Figure 7 – Ratio of no-shows over total appointments

5.2.6 Length of Stay

Figure 8 shows the 95% confidence interval for the mean length of stay per diagnosis. The blue area represents the confidence interval for the mean of the entire population.

The results show moderate variation in length of stay, even within diagnosis groups of many patients. Interval widths range from 120 to 590 days. Confidence intervals of diagnosis 1, 10, and 11 do not overlap with the population, indicating these patients have a statistically significant different length of stay than random patients from the total population. Confidence intervals of most groups have large overlap indicating the means are not significantly different.

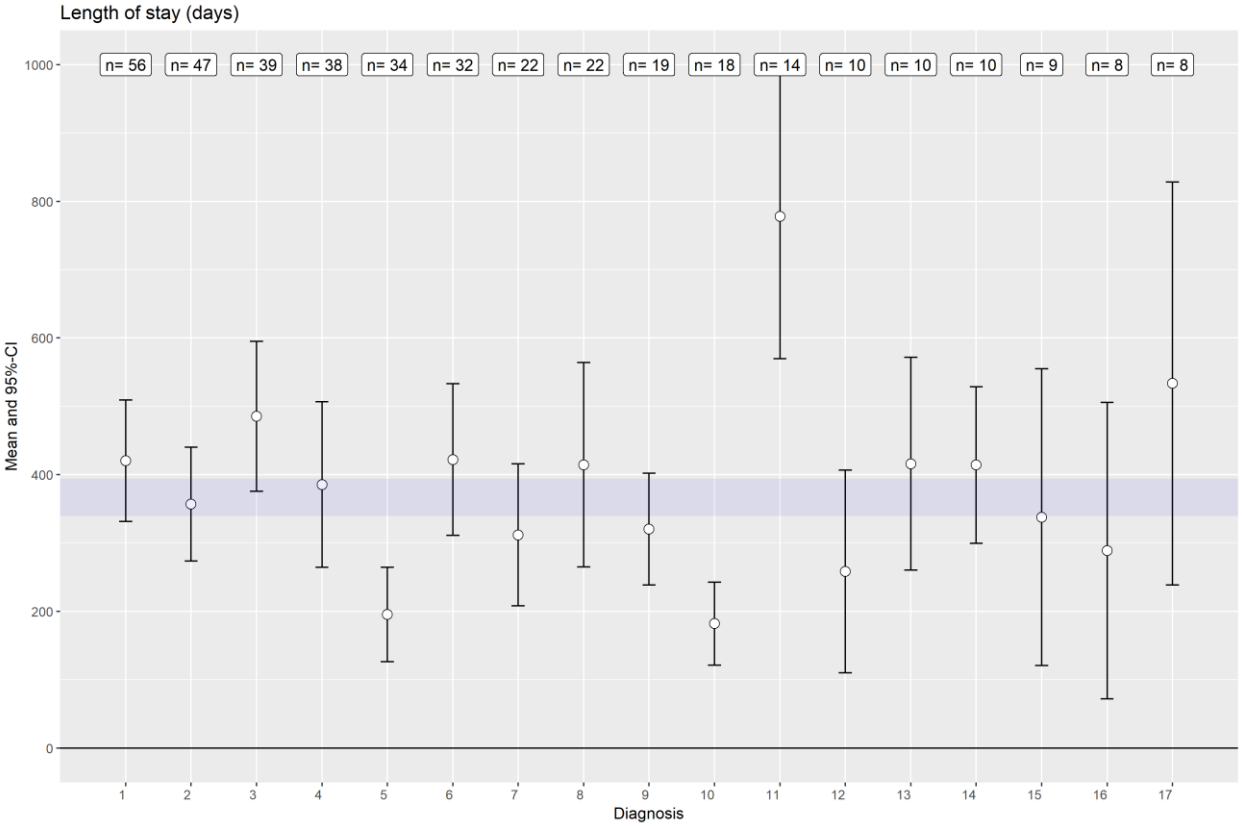


Figure 8 – Length of Stay per diagnosis

5.3 Conclusions

This section starts with an overview of the conclusions drawn from the results in the previous section, before answering Research Question IV: *"To what extent do patients with the same initial primary diagnosis place the same workload on the organization?"*.

The evaluated statistics per diagnosis show large variance. This implies the selected data contains too few samples, too many outliers, or that there is significant variance between patients of the same diagnosis. Grouping diagnoses to increase the number of samples per group could allow for better analysis. Table 12 shows how less than 10% of the data remained after selection. Particularly filtering by finished treatments and adults only removed a lot of samples.

Most confidence intervals per diagnosis have at least some overlap with the confidence interval of the entire population. This means no significant differences could be determined in those cases. There are only two cases where a diagnosis had statistically significantly higher means than the population average. These were diagnosis 8 requiring significantly more administrative tasks per day of treatment, and diagnosis 11 having a significantly longer Length of Stay.

Table 13 shows which diagnoses have statistically significantly different means than the total population per indicator.

Table 13 – Significantly different means per diagnoses relative to population per indicator

L = diagnosis has a lower mean than the combined population
H= diagnosis has a higher mean than the combined population

KPI Diagnosis:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Length of Stay					L					L	H						
Days between appointments																	
Administrative tasks				L	L		L	H		L		L				L	
MDOs per day of treatment				L													
No-show rate											L					L	L

Based on the available data it seems that primary diagnosis has only limited use as predictor of workload per patient. Confidence intervals are often too wide to draw statistically significant conclusions, but for some they show significantly different means on multiple indicators. There is no diagnosis that has narrow confidence intervals for every indicator, meaning patients with the same initial diagnosis rarely place the same workload on the organization.

6 Implementation plan

This chapter covers the steps required for implementing data analysis at Pro Juventus. Section 6.1 describes the project scope by examining available resources, time horizon and goals. Section 6.2 describes the intermediate steps to achieving the organization's goals. Section 6.3 describes which operations should be performed in the analysis stage. Section 6.4 explains how Pro Juventus can detect new patterns to include in the analysis in the future. Section 6.5 provides a road map for Pro Juventus with respect to the earlier sections in this chapter.

6.1 Project Scope

This section provides the scope of the recommended implementation of data analysis at Pro Juventus. Organization goals are defined first, followed by a time horizon and overview of available resources.

The desired information is to have predictions of patients care complexity as explained in Section 3.2. The data analysis should also support deciding which patient from the waiting list to start treatment for next. Finally, the data analysis should provide management insight into the patient population. No such reporting currently exists, and decisions are often made on "gut feelings" instead of quantified metrics.

The operations manager established the time horizon for the implementation to be at most two years. Any investments related to the project are limited to a maximum of €25.000. There is currently no expertise available within the organization related to data analysis or programming. Pro Juventus has several servers running for their IT facilities that could be utilized for analysis, depending on the required computational performance.

6.2 Intermediate steps

This section describes the intermediate steps towards implementing data analysis at Pro Juventus. It covers the steps from *Stages of analytics* from Section 4.2.2 and applies them to the organization. Figure 9 presents a visualization of the stages of analytics.

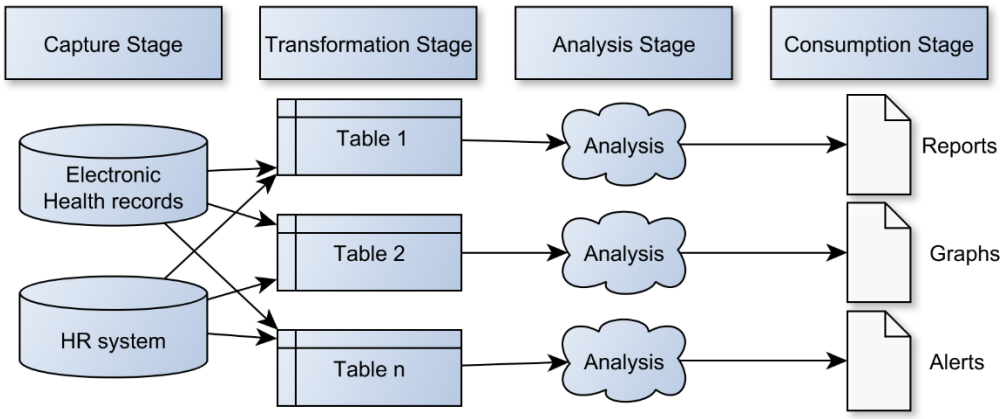


Figure 9 – Stages of analytics

6.2.1 Capture stage

The capture stage collects all data required for the analysis. This step should be automated to prevent the loss of data. For Pro Juventus, the capture stage is largely present. Most information will come from the electronic health records, which allows for direct exports to Excel workbooks. Data in these records is already collected for billing and care organization. HR also utilizes a system that allows exports to Excel.

The owner of Pro Juventus has indicated intake appointments might change soon by sending new patients a questionnaire beforehand. Answers to questions on this questionnaire, such as self-reported severity of complaints, should be stored in a way that is also compatible with Excel or easily converted to such a file. Finally, practitioners could be asked to start recording data about their patients, such as discharge estimates.

6.2.2 Transformation stage

The transformation stage prepares all collected data for analysis by cleaning it, converting it to more suitable file types, and combining different pieces of data into predetermined tables. For Pro Juventus, several steps are required. All test data and other erroneous data should be removed from the tables. All data prior to 2015 should also be removed because of the regulation changes. The staff IDs from the HR system and EHR systems should be converted to a single standard. Data types should be fixed for all non-text data. For example, dates should be converted to avoid sorting *'1-8-2018'* before *'2-1-2017'* and some text fields should be replaced by a Boolean (care path open or closed) or categorical value (treatment description). Because each analysis uses its own prepared table, it is possible to be flexible with selection criteria. For example, open treatments can be included when evaluating the rate of no-shows while they are excluded when determining total length of stay.

Certain tables need to be prepared or mutated for easy analysis. The exact mutations depend on the analysis to be performed. This means there is a standardized "clean up" for each source from the capture stage, followed by transformations specifically preparing data for one specific analysis. An example of this stage can be found in Figure 10.

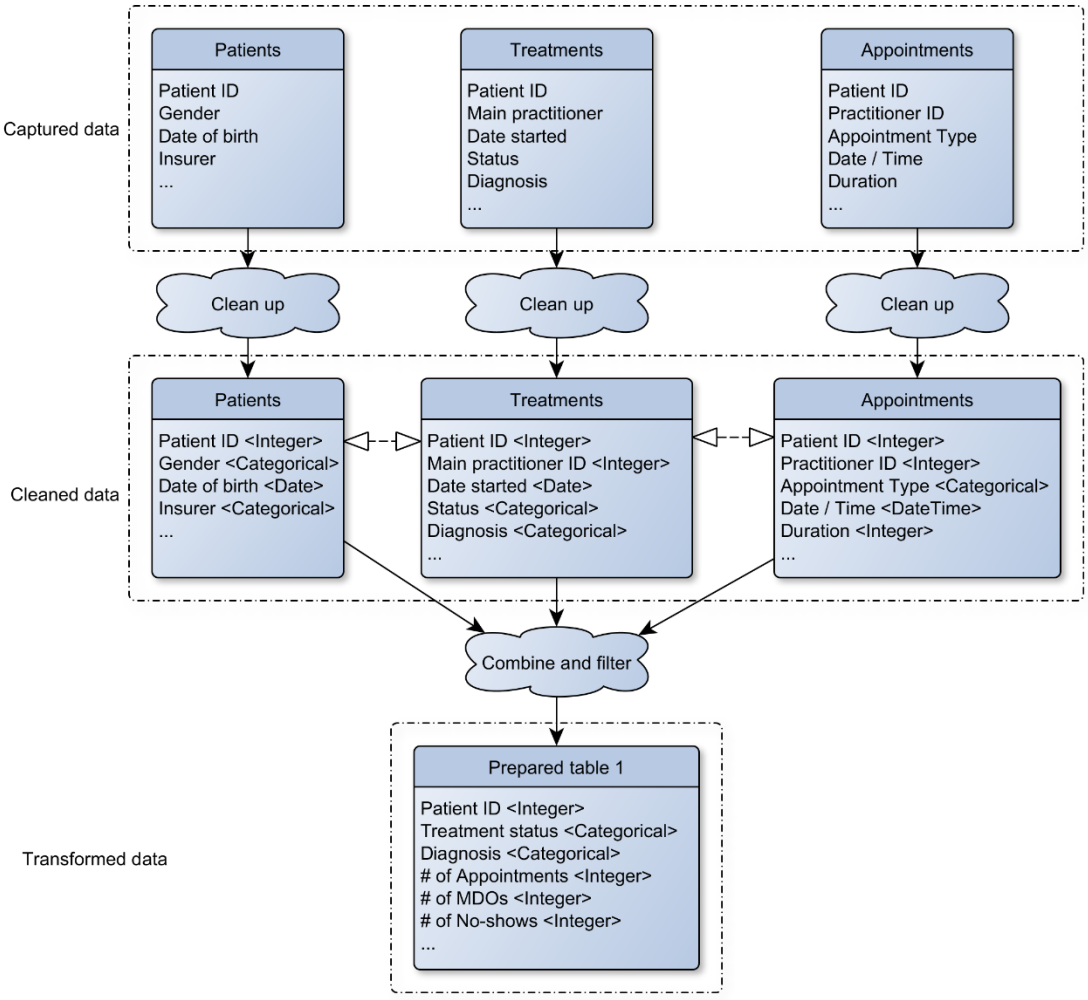


Figure 10 – Transformation stage example

6.2.3 Analysis stage

The analysis stage uses the output from the Transformation stage to run statistical tests or other types of analysis. The analysis stage heavily depends on the related level of analysis from Figure 2 on page 27. Output from this stage is passed to the Consumption stage. Figure 11 shows an example of how statistics per patient from the Transformation stage example could be processed to data per diagnosis, as a basic type of analysis.

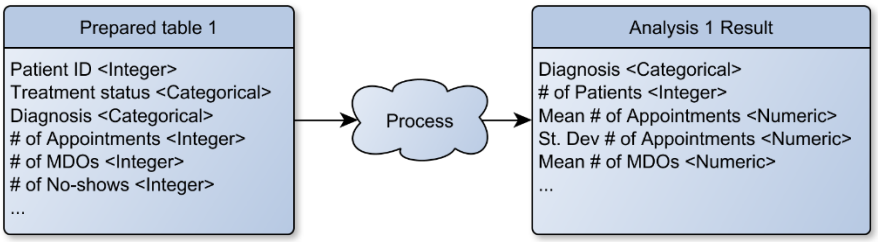


Figure 11 – Analysis stage example

Operations in the analysis stage should be reliable. This means operations should be deterministic, such as counting historic data, or the assumed statistical relationships should have been verified beforehand. This process is explained in Section 6.4.

6.2.4 Consumption stage

The consumption stage presents the results from the analysis stage in a convenient format for human interpretation. Depending on the analysis this could be an automatic report, a graph, or an alert. In advanced applications this presentation can also be interactive. It is important to choose a medium that suits the information. When communicating a trend over time it makes more sense to use a graph than a table, when displaying the waiting list it could be displayed as a list sorted by priority, while other information could be hidden entirely until it becomes relevant. Examples of the latter category are patients exceeding a certain ratio of no-shows or practitioners with productivity below a certain limit.

6.3 Analysis to implement

This section covers the different analytical operations that should be implemented at Pro Juventus. For each operation it also describes the required data to be prepared in the Transformation Stage as well as how the result should be presented in the Consumption stage. Each operation is related to one of the *Levels of data analysis* from Figure 2 on page 27. As explained in Section 4.2.2, the Prescriptive analytics require Predictive analytics which in turn require Descriptive analytics. This largely determines the order of implementing data analysis at Pro Juventus. Because of the limited resources, prescriptive analytics are considered an unrealistic goal for this roadmap.

6.3.1 Descriptive – Patient population

Pro Juventus currently has limited insight in its patient population. A report that describes current patient population can be generated by processing the electronic health records. A report like this helps management understand the current status of the organization better. This report should contain information such as:

- Table of core statistics
  - Number of patients per type of care
  - Number of appointments per type of care
  - Number of patients per diagnosis group
- Sorted list of patients with high workload (more than a configurable amount of FTE per month)
- Sorted list of patients exceeding a threshold for no-shows
- Sorted list of patients exceeding a threshold of MDOs

Compiling such a report requires data from the treatments table and from the appointments table to be combined into a table with the following columns:

- Patient ID
- Primary diagnosis
- Number of appointments
- Number of MDOs
- Number of no-shows
- Type of care
- Time spent on patient by practitioners

6.3.2 Descriptive – Practitioner overview

Pro Juventus currently does not have an automated way to measure practitioner productivity. It is currently done manually by the operations manager, by exporting and combining data from the electronic health records into a pre-made Excel sheet. Additionally, there is no easy way to see practitioner caseloads or compare practitioner performance on other metrics than productivity. A report with information listed below can help determine if practitioners perform similarly:

- Table of core statistics
    - Practitioner ID
    - Productivity
    - Number of active patients
    - Modal appointments before patient discharge
    - Mean patient no-shows
- Sorted list of practitioners by productivity
- Sorted list of practitioners by sick days

Compiling such an overview requires data from the treatments table and from the appointments table to be combined into a table containing the following columns:

- Practitioner ID
- Patient ID
- Number of appointments
- Number of patient no-shows
- Type of care
- Time spent on patient
- Treatment status (open, canceled, finished)

This means that for each practitioner, there should be a record per patient they have spent time on. Finally, a list must be compiled from the HR data containing the number of working hours per week for each practitioner and the number of days they've called in sick for.

6.3.3 Descriptive – Waiting list details

Pro Juventus can improve its knowledge about the waiting list if the pre-intake questionnaire from Section 6.2 is implemented. This overview should assist in which patient to start treatment for next. It should contain:

- Patient ID
- Priority
- Time on waiting list
- Referral origin (General practitioner, Hospital, Private care, etc.)
- Described symptoms
- Expected diagnosis (manually determined when processing the questionnaire)
- Self-reported severity
- Systemic factors (suffering relationships, poor job performance, insomnia, etc.)

This list would be mostly compiled during the transformation stage, with the priority calculated as a weighted sum from the other attributes.

6.3.4 Predictive – Estimated patient discharge

Further research is required to determine discharge predictors. Based on either literature research or further statistical analysis, predictors might be found that could be implemented in the data analysis for Pro Juventus. When a sufficiently reliable method of predictions, analysis should be included to provide a table of patients sorted by their estimated discharge date, including the related type of care and associated practitioners (whose caseload will go down after discharge).

6.3.5 Predictive – New patient care complexity

Section 5.3 concluded that patient diagnosis has limited use as predictor of care complexity. Therefore, more research is required to find better predictors that can be included in data analysis at Pro Juventus. Examples of factors still unexplored are age, gender, postal codes, appointment frequency and diagnosis groups instead of the primary diagnosis itself.

6.4 Discovering new patterns

As mentioned in Section 6.2, operations in the Analysis stage must be reliable. The relations and patterns in the data must be discovered, tested and understood before being implemented in the reports for management. Otherwise management could base decisions on incorrect information. That process is spearheaded by exploratory data analysis (EDA).

EDA consists of visualizing the data in different ways to understand the data and look for patterns. Examples are plotting histograms, dot plots and scatterplots. Hypotheses can be based on the visualizations and tested for more deliberately than otherwise possible, providing direction to the analyst. As written in *R for Data Science* (Grolemund & Wickham, 2017):

> *"EDA is not a formal process with a strict set of rules. […] During the initial phases of EDA you should feel free to investigate every idea that occurs to you. Some of these ideas will pan out, and some will be dead ends. As your exploration continues, you will home in on a few particularly productive areas that you'll eventually write up and communicate to others."*

6.5 Road map

The road map for Pro Juventus is based on the resources listed in Section 6.1. There is no budget to hire a full-time analysist. Instead, there are three options:

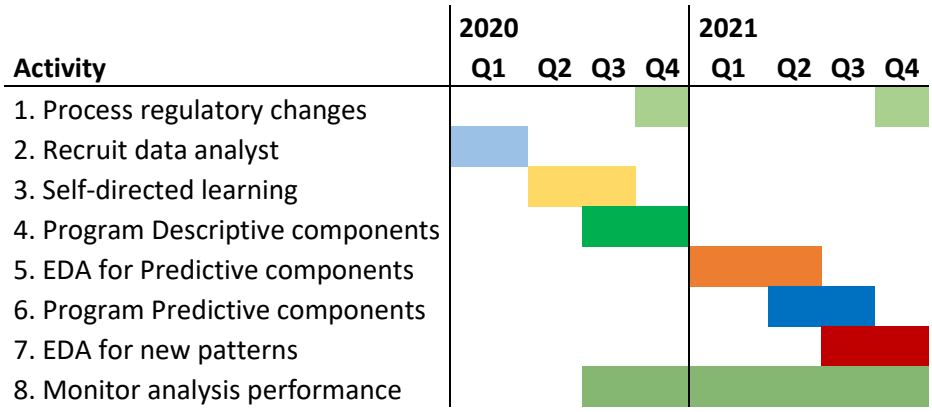
1. A part-time junior analyst can be hired at 0.2 FTE from a secondment agency. This will cost roughly €10.400 per year, assuming €40.000 full-time annual salary plus 30% overhead (vacation money, pension and health premiums, etc.).
2. Consecutive undergraduate or graduate students from programs like *MSc Data Science and Technology, BSc Business and IT* or *BSc Technical Computer Science* could be contracted as interns at roughly €400 per month. While this is cheaper, this is not recommended because of an expected productivity loss when transitioning from one student to another.
3. Implementation can be outsourced to a third party. It is uncertain whether this is feasible within the given budget.

For Pro Juventus, programming scripts in R using RStudio is recommended. R is widely used programming language with a large community and wide range of available packages. RStudio is a commonly used development environment that is published under an AGPL license, making it free if only used internally at Pro Juventus (Affero, sd). A benefit of these tools is that it requires no special hardware, and training material is available at numerous free and commercial providers. A list of training material and reference work is compiled in Appendix 8.4. Additionally, scripts written during this research can be repurposed when implementing the first steps of the roadmap. The final motivation is that R can be integrated with big data platforms such as Apache Hadoop, making it a very scalable tool.

Table 14 shows a suggested timeline for the implementation of data analysis at Pro Juventus. Data driven operations management becomes available as the implementation progresses. The roadmap assumes hiring a part-time analyst.

- Activity 1 is an annually recurring task. Every year the NZa publishes changes to regulation for the upcoming year. The impact of these changes needs to be evaluated so that analysis is still reliable next year. This potentially means improving the transformation stage for parts of the data.
- Activity 2 consists of hiring a part-time analyst. This person needs to have a background in statistics and computer programming. Experience with R specifically is not required.
- Activity 3 is the self-directed learning by the analyst. The analyst will need to learn about the organization, about regulation (to correctly interpret the electronic health records), about the meta-data and the limitations. Getting familiar with R is also included in this activity.
- Activity 4 consists of programming the transformation, analysis and consumption for the descriptive components listed in Section 6.3. Implementing these can support learning the language and getting familiar with the data, which explains the overlap with Activity 3.
- Activity 5 refers to EDA into the described predictive components. As this research was not yet conclusive about how to estimate patient discharges or new patient's care complexity, the data must be explored for currently undiscovered predictors.
- Activity 6 consists of implementing the discovered patterns.
- Activity 7 is searching for further patterns and relations in the data, potentially giving new insights.
- Activity 8 includes periodic evaluation of the implemented analyses, improving their accuracy and adjusting analyses to information requests from management.

Table 14 – Implementation road map



Near the end of the project, management must decide whether they want to keep investing in improving their analytics, and how many resources will be allocated in case of an extension. An important factor in this decision is the annual regulation update, meaning that without extension the work from this project might become obsolete.

7 Conclusion and recommendations

This chapter concludes the main research question: *"How can data driven operations management support the primary process of Pro Juventus?"* Section 7.1 answers the main research question. Section 7.2 provides recommendations to the problem owner. Section 7.3 provides recommendations for future research.

7.1 Conclusion

Data driven operations management based on the collected electronic health records can provide limited value to Pro Juventus. As mentioned in Section 3.3, the proportion of G-GGZ patients had grown much further than management anticipated. Certain diagnoses have been identified with a lower than average associated workload across performance indicators in Section 5.3. Patients with these diagnoses can be prioritized from the waiting list when there is only limited capacity. However, limited sample sizes have prevented identification of more detailed patterns or relationships. The electronic health records have proven less suitable for analysis than anticipated at the start of this research.

7.2 Recommendations for the problem owner

Based on the assessment of the current workload in Section 3.3, optimizations to G-GGZ care at Pro Juventus are likely to provide the largest benefits to the organization. Future data driven projects should have a clear definition of what the organization is trying to learn, so that data can be collected specifically for that goal. Repurposing the electronic health records requires very intensive data preparation before any analysis can be performed, and potentially requires updating after every regulation change. This makes the electronic health records less suitable than anticipated. This conclusion is confirmed by literature in Section 4.2.

Adhering to the stages of data analytics described in Section 4.2.2 will be extremely important to enable more thorough analysis of available data. Especially the transformation stage, where the raw data is prepared for analysis, has proven to be crucial during this research. Intermediate "building blocks" need to be programmed that translate records from various dates into a uniform data schema ready for further processing.

Future analysis of the electronic health records can include open care paths to increase sample sizes if length of stay is dropped as an indicator and all other indicators are taken with respect to time or total appointments. Additionally, a better definition is required for the end of treatment to prevent recurring medication checks from polluting the dataset.

To establish proper analytics, an implementation plan is proposed in Chapter 6. This plan includes a road map that helps Pro Juventus establish descriptive and predictive analytics from of the *Levels of data analysis* from Figure 2 on page 27 within the allocated budget.

7.3 Recommendations for future research

This research focused on the predictive value of patients' primary diagnosis. More research could be performed to assess the predictive value of other metrics such as GAF score at intake, age, gender, and the care profiles assigned to youth. Diagnoses could also be grouped for larger sample sizes, allowing for more statistically significant conclusions. Data selection should be reconsidered as well, to remove variance introduced by patients with recurring medication checks. As shown in Table 12, removing open treatments and youth patients removed immense numbers of patients as well.

Future research should start with a broader scope than this project. By heavily focusing on the predictive value of primary diagnoses, it is possible that more worthwhile patterns have been overseen.

Research regarding discharges in mental health care is currently extremely lacking. New studies about this topic could prove valuable to mental health care providers worldwide. A possible approach for this research is to conduct interviews with practitioners, as their decision process the main cause for patient discharges. The results from these interviews could be used as a starting point for exploratory data analysis as explained in Section 6.4, or as indication of which new data should be collected and evaluated. Additionally, the impact of attributes like age, gender, postal codes and appointment frequency has not yet been evaluated.

A limitation of this research is that closed treatments within the evaluated period might not be representative of average treatments. If care paths are regularly longer than four years – the period evaluated in this research – indicators such as the mean length of stay appear lower than reality. This is a form of selection bias. Repeating this research with data over a longer horizon could mitigate this problem, as well as evaluating different KPIs with different data selection criteria. For example, open care paths can be included when evaluating the ratio of no-shows to a specific patient's total appointments.

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8 Appendices

8.1 Literature queries and results

Very broad queries, not yet filtered for date or prominence (citations), still yield limited results in both Scopus and Web of Science databases.

Table 15 – Initial literature queries (Scopus)

Query	Number of results	Comment
TITLE-ABS-KEY ("mental health care" AND "operations management")	1	Full text not available
TITLE-ABS-KEY ("mental" AND "operations management")	21	Irrelevant articles such as a "review of Japanese companies after the 2011 earthquake" and US Veteran care.
TITLE-ABS-KEY ("mental health care" AND "operations")	356	Mostly about how care is provided or where care is needed, such as veteran care, depression among police forces, or providing care over the internet.
TITLE-ABS-KEY ("mental health care" AND "electronic health records")	114	Limited relevance
TITLE-ABS-KEY ("mental health care" AND "informatics")	100	Limited relevance, overlap with previous queries
TITLE-ABS-KEY ("mental health care" AND "decision support")	133	Limited relevance, mostly about involving stakeholders such as family

Table 16 – Initial literature queries (Web of Science)

Query	Number of results	Comment
TS=("mental health care" AND "operations management")	0	
TS=("mental" AND "operations management")	8	None relevant
TS=("mental health care" AND "operations")	49	None relevant
TS=("mental health care" AND "electronic health record")*	34	Limited relevance
TS=("mental health" AND "informatics")	136	Limited relevance, overlap with previous queries

8.2 Literature topic brainstorm

A mind map was built to come up with other topics for literature. Each node was considered as topic after the map was finished.

Figure 12 – Literature topic brainstorm

8.3 Numerical results per primary diagnosis

Table 17 – Indicator means per diagnosis

	Means	Patients	LoS (days)	Days between Apts	Administrative tasks per day	MDOs per day	No-show rate
	Population:	503	367	15,3	0,012	0,011	1,7%
	Diagnosis:						
1	Aandachtstekortstoornis met hyperactiviteit: Overwegend onoplettendheid type	56	420	15,7	0,01	0,005	2,4%
2	Autistische stoornis	47	357	12,7	0,013	0,011	1,6%
3	Aandachtstekortstoornis met hyperactiviteit: Gecombineerde type	39	486	18,6	0,009	0,055	2,4%
4	Posttraumatische stress-stoornis	38	386	14,8	0,001	0,001	1,2%
5	Posttraumatische stress-stoornis: Met verlaat begin	34	196	12,4	0,002	0,008	1,3%
6	Pervasieve ontwikkelingsstoornis NAO	32	422	17,6	0,012	0,002	3,9%
7	Depressieve stoornis: Eenmalige episode, Matig	22	312	15,0	0,003	0,018	2,2%
8	Persoonlijkheidsstoornis nao	22	415	11,8	0,033	0,013	0,8%
9	Dysthyme stoornis	19	320	16,4	0,011	0,003	1,1%
10	Angststoornis NAO	18	182	15,7	0,001	0,005	1,9%
11	Stoornis van Asperger	14	778	17,8	0,006	0,002	0,5%
12	Depressieve stoornis NAO	10	259	16,8	0,001	0,018	0,4%
13	Paniekstoornis zonder agorafobie	10	416	22,1	0,036	0,002	1,0%
14	Sociale fobie	10	414	13,6	0,009	0,005	4,6%
15	Gegeneraliseerde angststoornis	9	338	13,8	0,032	0,004	1,4%
16	Depressieve stoornis: Recidiverend, Matig	8	289	12,2	0,003	0,007	0,3%
17	Obsessieve-compulsieve stoornis	8	534	18,5	0,006	0,003	0,2%

Table 18 – Indicator confidence interval widths per diagnosis

	95%-CI half width	Patients	LoS (days)	Days between Apts	Administrative tasks per day	MDOs per day	No-show rate
	Population:	503	27	0,9	0,003	0,008	0,4%
	Diagnosis:						
1	Aandachtstekortstoornis met hyperactiviteit: Overwegend onoplettendheid type	56	89	2,1	0,004	0,002	1,3%
2	Autistische stoornis	47	83	1,8	0,005	0,006	1,1%
3	Aandachtstekortstoornis met hyperactiviteit: Gecombineerde type	39	110	5,0	0,006	0,100	1,6%
4	Posttraumatische stress-stoornis	38	121	2,7	0,001	0,000	1,5%
5	Posttraumatische stress-stoornis: Met verlaat begin	34	69	2,0	0,003	0,006	1,1%
6	Pervasieve ontwikkelingsstoornis NAO	32	111	3,7	0,015	0,002	3,6%
7	Depressieve stoornis: Eenmalige episode, Matig	22	104	4,5	0,002	0,022	2,2%
8	Persoonlijkheidsstoornis nao	22	149	3,7	0,018	0,007	0,9%
9	Dysthyme stoornis	19	82	4,1	0,011	0,003	1,2%
10	Angststoornis NAO	18	61	3,3	0,002	0,004	2,5%
11	Stoornis van Asperger	14	208	4,1	0,004	0,002	0,7%
12	Depressieve stoornis NAO	10	148	6,8	0,001	0,028	0,9%
13	Paniekstoornis zonder agorafobie	10	156	8,2	0,065	0,002	1,3%
14	Sociale fobie	10	115	2,3	0,007	0,003	3,7%
15	Gegeneraliseerde angststoornis	9	217	4,6	0,054	0,006	2,2%
16	Depressieve stoornis: Recidiverend, Matig	8	217	5,1	0,003	0,007	0,5%
17	Obsessieve-compulsieve stoornis	8	295	8,6	0,006	0,002	0,4%

8.4 Reference and training material for R

This appendix lists reference and training materials for programming in R.

Codecademy course "Learn R" - https://www.codecademy.com/learn/learn-r
An interactive online course for programming in R, directed towards data science. Provides online solution checking for the exercises. Comes in a free and subscription-based version.

Computerphile playlist "Data Analysis with Dr Mike Pound" - https://www.youtube.com/playlist?list=PLzH6n4zXuckpfMu_4Ff8E7Z1behQks5ba
A playlist on YouTube containing videos about data analysis in R by Dr. Mike Pound, lecturer and researcher in Computer Science at Nottingham University.

Hands-On Programming with R - https://rstudio-education.github.io/hopr/
A free e-book offering an introduction to R for non-programmers. Suitable as early training material.

R for Data Science - https://r4ds.had.co.nz/
A free, expansive e-book for data analysis in R. It assumes no prior knowledge about R. Can be used as both training and reference material. Also covers EDA in detail.

R Markdown: The Definitive Guide - **https://bookdown.org/yihui/rmarkdown/**
A free e-book regarding R Markdown, a combination of R and text to build completely automated reports. Suitable as reference material.

RStudio Cheat Sheets - https://www.rstudio.com/resources/cheatsheets/
Thematic reference materials for R. Especially *"Data Visualization with ggplot2"* and "Data *Transformation with dplyr"* can be relevant.

RStudio Shiny training materials - https://shiny.rstudio.com/tutorial/
A compilation of video and written tutorials on making interactive applications in R. Suitable as advanced training material.

Udacity course "Data Analysis with R by Facebook" - https://eu.udacity.com/course/data-analysis-with-r--ud651
Free online course for data analysis with R that includes assignments, instruction videos and exercises. Requires basic statistical understanding. Suitable as training material.