2021

Design of a developer tool to make the impact of events or decisions visual

at Senz Interim

Bachelor thesis Industrial Engineering and Management

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Univeristy of Twente
July 2021

UNIVERSITY OF TWENTE.

Senz Interim
kennispartner in onderwijslogistiek

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Preface

This report contains the bachelor thesis 'Design of a developer tool to make the impact of events or decisions visual at Senz Interim'. The research described within this report has been performed at Senz Interim in Enschede as a final assignment to complete my bachelor's program Industrial Engineering and Management at the University of Twente.

I want to thank Senz Interim for giving me the opportunity to do research at their company. I want to thank all of the colleagues at Senz Interim for their hospitality and collaboration to be able to conduct the thesis in a pleasant way. Besides, I especially want to thank Hendrik-Jan Kamp, my company's supervisor, for the support and guidance during my thesis. Additionally, I want to thank Jeroen Overmars for giving useful insights and supporting me with the development of BI within Senz Interim.

I want to give special thanks to Gayane Sedrakyan, as supervisor from the University of Twente, for her great support, feedback and suggestions with regard to my research. I learned a lot in conducting research and academic writing due to her insights and involvement during my thesis. Moreover, I want to thank Asad Abdiesfandani for being the second supervisor of my bachelor thesis. Furthermore, I would like to thank my fellow student Daniël Roelink for keeping me motivated and his extensive feedback and suggestions on conducting my research.

Nathan Hoogendoorn

July 2021

Management summary

This bachelor thesis has been performed at Senz Interim in Enschede. Senz Interim is a knowledge partner within the domain of educational logistics and is mainly specialised to support scheduling and planning for institutions. In today's environment, sudden changes related to the clients of Senz Interim often occur, causing problems at a late stage within the process of planning and scheduling for institutions. These problems consist of non-feasible schedules, problems with capacities of classrooms and non-optimal schedules for institutions. The main reasons for the planning-related problems to occur is that, first, Senz Interim is not able to react proactively or predictively to the changes. Secondly, decisions are made with wrong insights in early stages of the planning process.

In order to solve these problems, a method has to be created to gain insights into the consequences of changes. Because of this, the aim of this research is to solve the following core problem: *'At Senz Interim, there are currently no transparent and visual methods to gain insights in the consequences of changes in the planning process consisting of visualising the feasibly between different variables (e.g. students, teachers and capacity)'*.

The method that has been chosen to generate visual insights, is the development of dashboards with the use of Business Intelligence (BI). Within these dashboards, one is able to gain insight into the current performance of an educational planning as well as the consequences of several changes. During the research, visualisations and insights will be generated for one educational institution, which will act as a prototype for the development of BI within Senz Interim.

The first step of the research is to identify relevant Key Performance Indicators (KPIs) that are able to visualise the performance of a planning as well as the consequences of a decision or event. The KPIs are identified by means of currently existing indicators and data, preferences of the consultants of Senz Interim and literature. The identified KPIs could be divided into six categories, namely 'Occupation online/ on location', 'Occupation per location', 'Student satisfaction', 'Teacher satisfaction', 'Requested occupancy versus actual utilisation' and 'Registrations academic year'. Finally, three different what-if scenarios are identified that are able to simulate changes, and impact the KPIs related to educational planning. These scenarios consist of changes in the room capacities, number of online lessons given and student registrations.

Dashboard visualisation is a crucial part of this research and, therefore, is investigated. Effective and user-friendly dashboards are important for the interpretation and communication of the visualisations. Dashboard design guidelines as well as interactivities and graph transparencies are analysed by means of a literature study to be able to gain knowledge regarding effective dashboard visualisations.

The dashboards can be developed with the use of various BI tools available on the market. A selection of various BI tools has been used in order to find the most suitable BI tool for this research.). The tools were assessed on several criteria established during communication with multiple consultants with the use of the Analytical Hierarchy Process (AHP). The visualisation possibilities, cost, user-friendliness and the possibility for a mobile app are taken into account as decision criteria. Concluded, Tableau was found to be the most suitable BI tool for this research.

Using Tableau, dashboards have been created and implemented with the data of one institution as well as dummy data. Within these dashboards, the identified KPIs that were possible to visualise are shown along with the what-if scenarios.

Concluded, the implemented dashboards are able to visualise consequences of a decisions and, thus, were able to solve the core problem. The created dashboards are able to show the current performance of a planning together with the impact of the scenario changes on the indicators. It is recommended that Senz Interim will continue with the development of BI and make a standard product that is applicable for multiple institutions with the use of a Data Warehouse (DWH) and Tableau. Furthermore, the tool should be kept up-to-date and more scenarios can be implemented that are able to solve more sudden issues that might occur in the near future. Finally, instead of pre-established dashboards, the option that a user is able to compile its own dashboard and choose the visualisations he/she wants to see is recommended.

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Reader’s guide

This research is structured in six chapters, which are briefly introduced below.

Chapter 1 – Introduction
The first chapter of this report provides an introduction to this research. Within this chapter, an introduction of the company as well as the problem statement with the defined core problem is given. Moreover, this chapter elaborates on the methodology behind this research within the research design, consisting of research questions and approach of this research.

Chapter 2 – Key performance indicators
This chapter focuses on the key performance indicators that are applicable for this research. The key performance indicators are based on the existing situation, preferences of the consultants and literature. Additionally, the data needed to create the established key performance indicators as well as the what-if scenarios applicable are described.

Chapter 3 – Dashboard visualisation
Literature study regarding dashboards and visualisations is described within the third chapter. This chapter, first, gives an elaboration on the concept of dashboards. Besides, design guidelines, interactivities and graph transparency that all can influence the effectiveness of dashboards to users are provided.

Chapter 4 – Solution design
The fourth chapter of this report focuses on the solution design. More specifically, a decision making process named ‘AHP’ is used in order to find the most suitable BI tool for this research that is able to visualise the proposed key performance indicators. The decision criteria as well as the decision alternatives are described next to the results of the process.

Chapter 5 – Implementation
This chapter can be seen as the results of this research and provides the implementation of the visualisations that were made. The various dashboards, visualised key performance indicators and scenarios are discussed within this fifth chapter.

Chapter 6 – Conclusion, recommendations and limitations
The last chapter concludes whether the developed dashboards meet a valid solution to the core problem. Moreover, recommendations and limitations regarding the performed research are given within this chapter.

Definitions

BI – Business Intelligence (BI) is a term that describes concepts and methods to improve business decision making by translating data into valuable insights with the use of software and services.

Dashboard – A dashboard collects, summarizes and presents information for multiple sources (Yigitbasioglu & Velcu, 2012). A dashboard can improve decision making by visualising several relationships between variables and will be used to clearly and visually show the consequences of a decision within educational planning with the use of several KPIs.

Dummy data – Mock-up data that is (randomly) generated and serves as a substitute or alternative for real data. Dummy data is often used within testing environments.

DWH – A Data warehouse (DWH) is a central repository for data of one or multiple sources. A DWH is often used within business intelligence and is used for reporting and data analysis.

KPI – Key Performance Indicators (KPIs) are indicators are able to show the level of performance that a system is achieving through measurable attributes (Brundage et al., 2017). Key Performance Indicators are crucial in measuring and improving the performance of a current system.

1. Introduction

This chapter outlines an introduction to Senz Interim as well as the purpose of my research. Section 1.1. presents an introduction to the working domain and way of operating of Senz Interim. Section 1.2. defines the problem statement including the action problem that is applicable, the problem identification and motivation of the chosen core problem. Section 1.3. describes the research design, consisting of research and knowledge questions of my thesis as well as the type of research I will be using and the problem scope.

1.1. Company description

Senz Interim is a knowledge partner specialised in the domain of educational logics, founded in 2014. Educational logistics includes the whole Student Life Cycle, from a student orientating for a certain education path until graduating and everything that comes with it. Senz Interim has clients in the form of educational institutions all across the Netherlands and is active in supporting different levels of education, from high schools till universities.

The assignments that Senz Interim carries out are on a tactical and strategic level and cover the entire educational logistics of an institution. Currently, Senz Interim consists of eight consultants and multiple schedulers / educational planners. The employees within the company use their experience and knowledge within educational institutions to realize ambitions. These ambitions are mostly in the form of improvement and implementation processes. The consultants of Senz Interim are, therefore, mainly encountered at management and board level.

Figure 1; Logo of Senz Interim

Currently, Senz Interim is mainly specialised to support scheduling and planning for their clients. Approximately 90 percent of the assignments Senz Interim carries out have to do with planning and scheduling of institutions. These assignments are for a part concerned with supporting the implementation of new applications and systems (e.g. grating systems or student tracking systems) regarding educational planning. In addition, analysis of current planning processes of institutions are often conducted to address improvement points and give advice on the way a schedule is being made. For this, the consultants of Senz Interim are often closely connected to the actual educational planners Lastly, planning and schedule assignments also deal with training and coaching within the domain of educational planning.

The remaining 10 percent can be seen as talent analysis of employees. Improvement points are addressed during this analysis to persons intern as well as extern of the company to develop skills regarding educational logistics.

Senz Interim themselves do not actively seek for clients with the use of advertisement themselves, conversely educational institutions often directly contact Senz Interim for an assignment. Institutions can get in touch with Senz Interim via internet, intermediate parties or because institutions have good experiences with assignments that were carried out previously. Especially the good reputation within the market combined with a large network causes the majority of assignments.

When an institution has an assignment available, Senz Interim first wants to clarify the specific needs and requirements of the task. This implies the knowledge needed and timeframe for which the assignment needs to be carried out. To frame the agreements of a task (what is and what is not required to do), Senz Interim is able to work more effectively and efficiently.

As of right now, there are circa fifteen different institutions for which assignments are being carried out. Five of these institutions together account for approximately 85 percent of the total revenue generated.

The consultants of Senz Interim all possess their own skills and specialities. Depending on the type of assignment, a set of consultants is appointed to a specific task. There is continuous communication between all of the consultants of Senz Interim to support each other in carrying out the different assignments.

1.2. Problem statement

This section outlines the problem statement regarding my research at Senz Interim. First, the action problem of the thesis is defined. Moreover, a problem identification is given by means of establishing a problem cluster. Finally, the core problem is specified including motivation.

1.2.1. Action problem

Within Senz Interim, there are often problems within the process of planning and scheduling for institutions. Because of sudden changes related to the clients of Senz Interim, a problem is that schedules are sometimes found to be not feasible during later phases within the process. An action problem can be defined based on this situation that the company currently faces.

An action problem describes the difference between norm and reality in the eyes of the problem owner (Heerkens & van Winden, 2017), the problem owner is Senz Interim in this case. Moreover, in reality there are currently many issues that are encountered at a late stage of scheduling. These problems are related to the domain of educational planning, such as not fitting schedules for a situation within an institution. Senz Interim wants to prevent these problems from occurring at a late stage of the planning process. This means that the company wants to minimize problems with scheduling, so that issues occurring at a later stage of the planning process can be prevented.

When looking at the norm and reality, currently there is a discrepancy between them. This means that an action problem can be defined related to my bachelor thesis which is as follow:

> ***"At Senz Interim, too many problems related to educational planning are found during a late stage of scheduling"***

1.2.2. Problem identification

A problem cluster is provided and can be seen in Figure 2, which has been identified after conducting several interviews with the employees of Senz Interim. Within the problem cluster, all of the current problems that occur within Senz Interim are shown. Moreover, the relationship between the problems is visualised with the use of arrows, which aim to point from a cause to a resulting effect. A distinction between three types of problem can be seen within the problem cluster, namely normal (follow-up) "Problems", "Core problems" and the previously defined "Action problem".

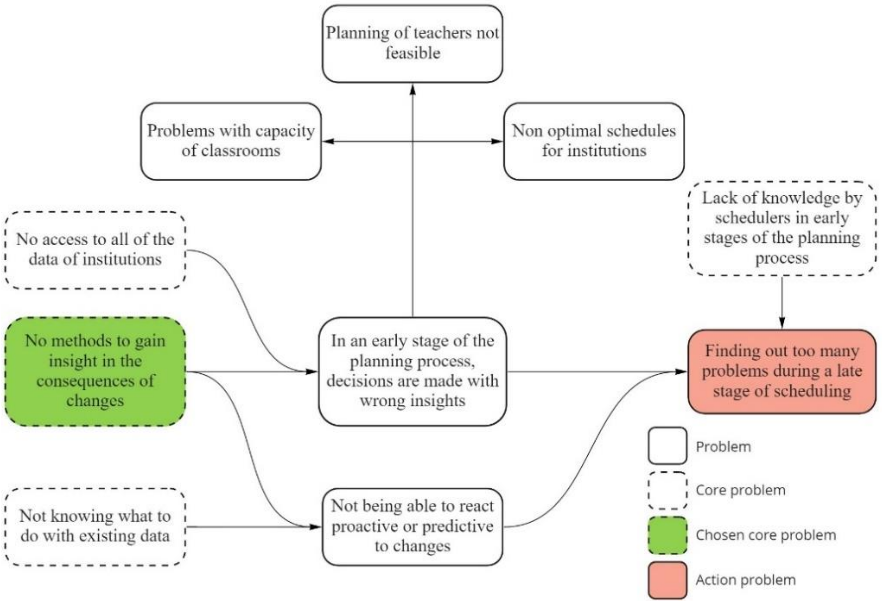

Figure 2; Problem cluster

Additional explanation of the problem cluster is provided in Appendix A. Here, all of the problems that currently occur at Senz Interim are explicitly described including the relationships with other problems.

1.2.3. Core problem and motivation

With the problem cluster that can be seen in Figure 2, multiple core problems can be identified. A core problem can be found in the root of the problem cluster, resulting in other problems (Heerkens & van Winden, 2017). In total, Senz Interim has four different candidate core problems:

1) No access to all of the data of institutions
2) Lack of knowledge by schedulers in early stages of the planning process (not skilled for optimising a planning)
3) No methods to gain insight in the consequences of changes
4) Not knowing what to do with existing data

The candidate core problems first need to be investigated more thoroughly to select the core problem that I will focus on during my bachelor thesis. As can be observed, the first of the four core problems cannot be easily solved, as this is mainly a privacy issue. The second problem can be seen as a (knowledge) management related problem within the company as this problem is mainly about the knowledge of schedulers. Because of this, the second candidate core problem has no potential to be addressed within this thesis work. Out of the remaining core problems left, the most important problem should be focused on those that may have the greatest impact (Heerkens & van Winden, 2017). Both of these candidates are suitable for further study, however the third candidate problem was observed to result in a higher number of other problems according to the problem cluster. This suggests that solving the third core problem would result in more other problems to be solved and, thus, can have the highest impact and priority. For this reason this thesis will focus on the third core problem, namely methodological support to gain insight in the consequences of changes.

The formulation of the chosen core problem needs some refinements. First of all, the problem owner and norm and reality should be expressed within the core problem (Heerkens & van Winden, 2017). The problem owner is Senz Interim. Additionally, there currently are no methods to get insight into the consequences of changes in the planning process. This can be seen as the reality part of the core problem. Senz Interim wants to visually see the consequences (outlines) of a decision or event within the planning process. Senz Interim preferably wants a dashboard including visual representations of the consequences of a changed factor. Next to being able to visually see the consequences, there needs to be transparency. This can be seen as the norm of the core problem.

Additionally, the chosen core problem should be made measurable in order to see if a certain solution solves this core problem. During my research, I will explore which KPIs can be relevant to give insights on the feasibility of a schedule. Several KPIs can also be used in order to make the chosen core problem measurable. These KPIs can be seen as concretising variables, which are used as indicators for parts of the problem (Heerkens & van Winden, 2017), contributing to the observation of a problem as a composition of sub-problems or sub-metrics. The main variables related to educational planning are students, teachers and capacity of a certain facility or classroom. Combinations of these variables together will form a basis of most of the KPIs that I will use during my thesis. These relationships between these variables can indicate the feasibility of a current schedule. So, in order to make the core problem measurable, the feasibility of relationships between students, teachers and capacities need to be made visible. Once this is made visible, one is able to conclude that the core problem has been solved.

Overall, when expressing the problem owner, norm and reality within the core problem and make it measurable, the core problem can be properly stated. The core problem that I will focus on during my bachelor thesis can be defined as follows:

> ***"At Senz Interim, there are currently no transparent and visual methods to gain insight in the consequences of changes in the planning process consisting of visualising the feasibility between different variables (e.g. students, teachers and capacity)"***

1.3. Research design

Towards solving the chosen core problem, research design gives structure to the search. The research design is based on the MPSM problem solving approach mentioned within the book Solving Managerial Problems Systematically (Heerkens & van Winden, 2017). The MPSM helps engineers to arrive at solutions according to a systematic and stepwise approach, from problem identification till solution implementation and evaluation. Within this section, the research design is described according to the research questions and the corresponding and more feasible knowledge questions. Additionally, the type of research that I will be using is provided.

1.3.1. Research and knowledge questions

1) **Which KPIs can be visualised to show the impact of a decision within educational planning?**
    a. What are the existing KPIs that are currently used at Senz Interim?
    b. Which KPIs do the consultants of Senz Interim prefer to be implemented?
    c. Which KPIs exist within the literature that can give Senz Interim insight into the consequences of a decision?
    d. Which data is needed to create the KPIs?
    e. What events of decisions can be simulated based on the KPIs?

First of all, it is necessary to identify KPIs that can be visualised in order to show the impact of an event or decision. For this, existing KPIs as well as preferences of the consultant of Senz Interim will be addressed. In addition, useful KPIs from the literature will be taken into account. When there is a clear overview of KPIs that are applicable for my research, data that can create the KPIs as well as decisions that can be simulated need to be identified.

2) **What type of dashboard and visualisations can be used to benefit the proposed KPIs?**
    a. What are design and layout guidelines for a dashboard?
    b. What type of interactivity would benefit the KPI dashboard? (e.g. filtering, comparison, sorting, zoom in, etc.)
    c. What types of graphs or charts can give the most transparency?

Second, it should be clear what type of dashboard and types of visualisations can be used to show the selected KPIs. Research will be conducted on dashboard design and layout guidelines as well as interactivity features that can benefit the visualisation and interpretation of KPIs. Moreover, the most transparent graph types to show the selected KPIs will be researched in order to make the dashboard effective and user friendly.

3) **What solution design and implementation can be recommended?**
    a. Which programs or applications are available for designing a developer tool?
    b. What are requirements for a program or application for visualising the impact of decisions?
    c. What program or application suits best for designing a developer tool that can meet the requirements?

Third, it is important to find the best program that is suitable for making a developer tool that meets the requirements of stakeholders. For this, available programs or applications will be identified and assessed based on several criteria. When the most applicable program is selected, work will be conducted on the solution design and implementation of the tool made for Senz Interim.

1.3.2. Type of research

This report targets a problem, in particular, a lack of transparent and visual methods to gain insight into the consequences of changes or decisions within the domain of educational planning. The methodology of my bachelor thesis will be based on qualitative research, which is seeking to develop understanding through description, that contributes to building theory (Schindler, 2019). Within this section, an elaboration is given on the methodology behind important steps toward a desired end result.

To form the problem statement including the action problem, problem identification and core problem, interviews with consultants of Senz Interim are used. More specifically, in total four in-depth interviews will be conducted (DiCicco-Bloom & Crabtree, 2006) with four different consultants of Senz Interim to identify and explore problems within the company.

Data analysis on the available data of clients (institutions) of Senz Interim will be used to get to know what KPIs can be identified with the data that is available. The types of data analysis that are applicable for my research are the descriptive and predictive analysis. A descriptive data analysis helps with giving valuable insights into raw or operational data and can indicate if something is wrong or right (Bekker, 2020). This type of data analysis is suitable for making dashboard by means of identifying KPIs, which is a large part of my research. A predictive data analysis tells what will happen and helps with predicting future trends or giving estimations for the future (Bekker, 2020). A predictive data analysis can manifest the consequences of a decision based on the resources of an institution by showing the impact of changing several variables.

In addition, individual in-depth interviews as well as group interviews (Frey & Fontana, 1991) will be conducted with all eight consultants of the company (including the director) to identify relevant KPIs that are applicable for my research.

Several knowledge questions will be answered according to literature study during my thesis. Literature will be used for finding KPIs related to educational planning as well as identifying guidelines for dashboard design, interactivity options and graph types. More precisely, a systematic literature review will be conducted to find the most transparent graph or chart types to visualise the KPIs. Moreover, literature will be applied to identify suitable programs that can be used to make a tool that can visualise consequences of a decision.

When it comes to selecting / validating KPIs, a selection will be made on the KPIs that are the most important and, thus, can have the greatest impact from the KPIs that were identified previously. Individual in-depth interviews with the company director and two consultants that are specialised within the domain of business intelligence will be conducted to select the most important KPIs during my research.

An important part of my research is designing a dashboard with the most relevant KPIs, relationships, clear visualisations that can show performance of the KPIs and input variables that a user can change to be able to show the consequences of a decision. For this, constant feedback of stakeholders from Senz Interim will be taken into account to get to a desired outcome.

1.3.3 Problem scope

There needs to be a focus for my research of creating a tool due to the limited amount of time of conducting my bachelor thesis. The main reason for this is that there exist different packages that are used for educational planning and educational logistics by Senz Interim (e.g. Osiris, Syllabus Plus, Xedule, TimeEdit, etc.) that can contain data about a situation and schedule of an institution. Different clients (institutions) of Senz Interim are working with various packages which all treat data differently. In other words, the datasets coming from the packages of clients can be reported in different programming languages/files (e.g. Excel, SOAP, XML, REST, SQL, etc.). This implies that making a BI tool that is applicable for all of the supported packages from institutions can become complex. A DWH/Middleware system can potentially be used to extract, transform and load all of the different types of data in a generic way. As a consequence, this intermediate 'station' of data can cause the BI tool to be applicable for all of the supported packages. Moreover, this will make data to be more maintainable and documented. The process described to make a BI tool that is applicable for multiple institutions can be seen in Figure 3.

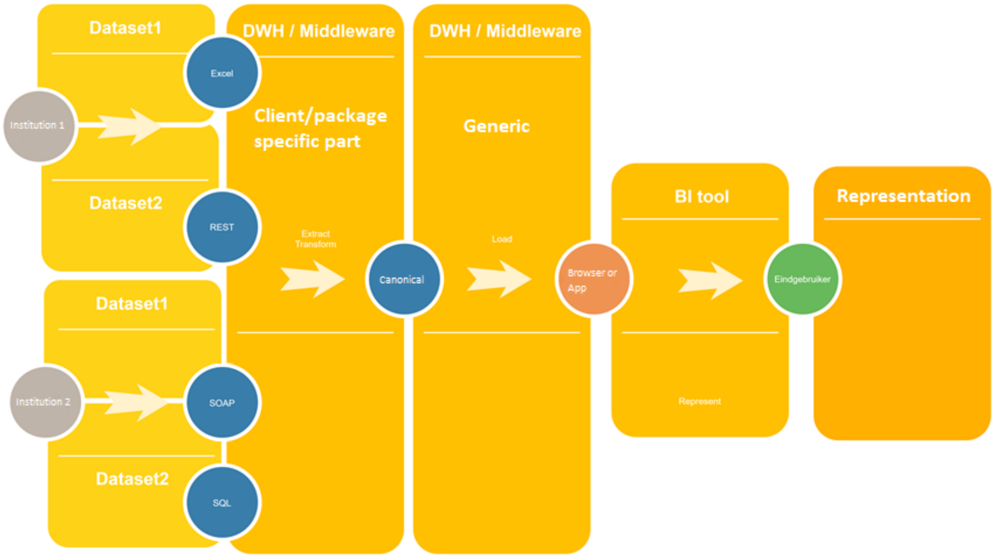

Figure 3; Roadmap including DWH/Middleware system

However, the development of a DWH/Middleware system will take a large amount of time and is stated as a long term process by Senz Interim. Therefore, my research will not focus on this aspect. Nonetheless, a more realistic perspective in the short term is that I will focus more on the development of the BI tool itself. This implies that identifying KPIs and researching visualizations by means of a dashboard is mainly the scope of my research. This will be done by the principle described within Figure 4, which shows that one dataset will be used in order to create a suitable dashboard for an end user. This can be seen as a prototype or proof of principle that can help Senz Interim in getting insight into the domain of educational planning of a client in the short term. This entails that I will not deliver a real product that can be utilized for all the clients, as the development can only be used once for a specific situation at an institution. However, the KPIs that will be shown within the prototype should be applicable for datasets of multiple institutions and not just the dataset of the prototype that I will make.

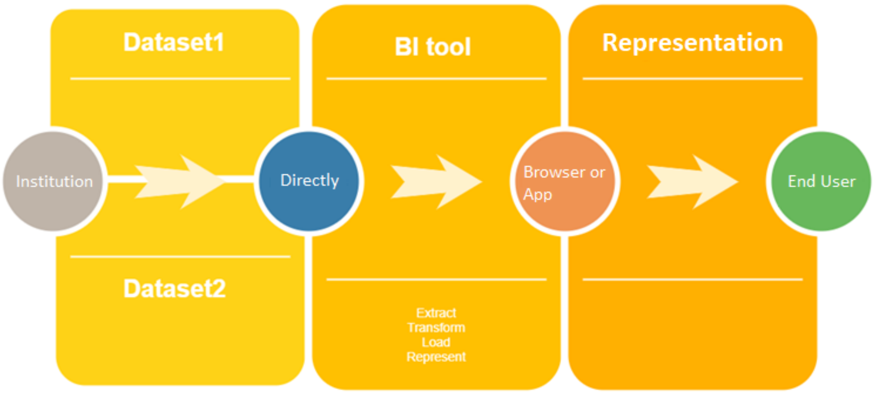

Figure 4; Roadmap problem scope

2. Key Performance Indicators

This chapter outlines the KPIs that are applicable for my research. This will be done by, first, defining the term 'KPI' in Section 2.1. Afterwards, existing KPIs that are used at Senz Interim are identified, which can be seen in Section 2.2. Section 2.3. describes the preferences of the consultants of Senz Interim, as stakeholders for my research, to detect the KPIs that they want to see. KPIs that are possible to construct after analysing existing data are also described within this section. Moreover, existing KPIs from applicable literature will be identified in Section 2.4. An overview is provided once all relevant KPIs are identified within Section 2.5. Section 2.6. elaborates on the data that is needed to create the pertinent KPIs. Finally, what-if scenarios that can simulate events or decisions are described within Section 2.7.

2.1. KPI definition

Every company and all manufacturers strive to improve their business performance, especially when lots of market competitions take place. Key Performance Indicators (KPIs) are indicators that designate the level of performance that a system is achieving through measurable attributes (Brundage et al., 2017). This implies that Key Performance Indicators can show the current performance of businesses and, therefore, are crucial in improving and optimising the performance of a current system. By making use of KPIs in the correct way, a company can potentially get ahead of its competition in the market.

KPIs can be applicable for creating transparency and supporting decision makers of managements for a wide range of sectors (Badawy et al., 2016). Particularly, visualising performance of several production processes with the use of KPIs can show meaningful trends and insights. The way KPIs are often visualised by means of a dashboard that collects, summarizes and presents information for multiple sources (Yigitbasioglu & Velcu, 2012). In other words, a dashboard enables a user to see business performance, shown by several KPIs, in a clear and transparent way.

During my research, KPIs will be used in order to show the current performance of an educational planning on a dashboard. Additionally, KPIs are also able to show the impact or consequences when changes happen within the current resources of an institution that allows one to make a course timetable. Visualising relevant KPIs can give purposeful insights to Senz Interim that can potentially reduce the number of problems found at a late stage of scheduling.

It is convenient to know that there is a distinction between different levels of education within the Netherlands (VO, MBO, HBO&WO) when it comes to educational planning. It is not realistic to deliver an end product with standard KPIs that are applicable for all education types. Reasons for this is that the way of working, processes and underlying legislation are too diverse among the different types of education. The prototype that will be made during my thesis is based on the higher forms of education (HBO and WO). This means that the KPIs that will be discussed within this chapter are based on the properties of these levels of education.

2.2. Existing KPIs

Within this section, relevant existing KPIs that are currently used at Senz Interim are identified. The existing KPIs were identified by means of conducting one interview with a business intelligence consultant and observations of the current tools that are used.

An already existing KPI that is used at Senz Interim is the occupancy or rather named presence of students at a moment in time. On an existing dashboard, the presence of all of the students from an institution is visualised by means of a heat map within a table. With the use of different colours of the heat map, it is shown when the occupancy of students is well or too high. Besides, a maximum occupancy of students is stated and it is visualised at what moment the number of students present at the institution exceeds this maximum occupancy. This was previously made to give the institution insights in their student occupancy with a normal capacity and the presence of students at the academy with a maximum capacity during the COVID-19 pandemic. With the use of the dashboard, Senz Interim offered this institution insights on when the student occupancy would exceed the maximum capacity during the pandemic.

In this existing KPI, a clear distinction is made between multiple course hours (blocks) of the college. The number of students present at a block of two hours is equal to the total amount of students that have a course scheduled during that specific block. Additionally, this KPI shows the number of students that are present at a block for each day and multiple weeks. Lastly, there are options to filter the heat map to a specific kind of education (study) and school year.

Another existing KPI is the number of changes/shifts in lessons at an institution, which is based on historical data of changes that happened during a certain period of time at the academy. An already established dashboard visualises the number of changes that a certain education encountered per week over a time period of six weeks in total. Different types of changes can occur, namely teacher replacements, moved course hours, changes in classrooms and even removed lessons. As of right now, the specific sort of changes per type of education are visualised by means of a table. Furthermore, a pie chart can be seen that clearly shows the percentage of total changes per study in comparison with other types of education at the institution. This can give insights to which studies are coping with the most timetable changes. In addition, this KPI can signal an institution that too many changes currently happen and that these changes should decrease in the future to reduce possible discomfort amongst the students and teachers.

2.3. Preferences of consultants

The KPIs discussed within this section are identified by means of interviews and brainstorm sessions with in total five consultants of Senz Interim combined with feedback and input from the director of the company. Moreover, existing data from clients was used and analysed in order to understand the possibilities for constructing KPIs from the available data. The identified KPIs can be divided into *six* categories described below.

2.3.1. Occupation online/on location

The first category is the occupation of lessons online and on location. Institutions have limited amounts of space available to provide lessons to their students. Additionally, more and more courses are given online due to the current pandemic. Because of this, a ratio originates between education that is provided online versus education on location (offline).

First of all, an insight can be given on the ratio between the online and offline lessons within an institution per quartile. This ratio can be given per education as well to gain insights in which studies have the most lessons online or on location. The mentioned ratio between the total of online and offline lessons within an institution can be compared with an average of an institution for example. This comparison can give insight in the performance of a current planning.

Second, the number of students on location per time period can be provided. This is an already existing KPI (explained in Section 2.1) which shows the number of students present per week, day and course hour. Besides, this insight can be given for a certain study quartile. The number of students present can even be show per study or study year. This insight is important to identify crowded and calm moments within an institution, from which an academy can make decisions on the amount of staff, supervision and space available.

2.3.2. Occupation per location

The second category focuses more on the occupation of a specific location at an institution. Insights within this category are useful from an operational, tactical and even strategic point of view. From an operational point of view, it can help schedulers/educational planners to estimate on which days or at what times specific types of rooms are still available. From a tactical point of view, it can help in making decisions to give a certain course a couple of hours later or online, for instance. Finally, from a strategic point of view, it can give insights in the cohesion between study offers and the availability of specific types of classrooms.

Within this category, insights can be given on the occupation as a percentage of the number of booked places (rooms) in comparison with the maximum amount of places. A distinction can be made between different types of facilities and classrooms. This can be shown for different time periods (days, weeks, quartiles). This insight can be given for different course hours, types of rooms, studies and study years.

2.3.3. Student satisfaction

High student satisfaction is of great importance for most educational institutions. There are many diverse ways to increase this student satisfaction, at which these ways are more concrete for one institution than the other. Within this category, a number of causes are made insightful that can help in determining the student satisfaction at an academy.

First, an insight can be given on the number of scheduled course hours after a certain time of day. For example, the amount of course hours after five o'clock in the afternoon. This is because students often prefer not to have lessons late in the afternoon, as there often are other activities planned in the afternoons or evenings. These lessons can therefore decrease the student satisfaction. This insight can be given per study and per quartile.

Second, the number and distribution of days with no lessons can be visualised. Lesson-free days can stimulate student satisfaction, however the distribution of these days can influence the satisfaction as well. An institution can indicate, for example, that lesson-free days at the end of a week/quartile are preferred over days with no lessons at the start of the quartile or week. Once again, this indicator can be shown per study of an institution.

Third, insights can be given on the number and distribution of course hours per day for a certain study. The number of distribution of course hours can play a big role in the student satisfaction, as many idle hours experienced by students can be of negative influence for instance. In addition, too many scheduled course hours per day can also influence the student satisfaction in a negative way.

The distribution of online and offline lessons per study fits within this category. There needs to be a good distribution between lessons that are given on location and online. If a great part of the lessons are given online, a student can experience this negatively. This is because there is less social contact and no convenient interaction between students and teachers within online lessons. This is exactly why this indicator can be of importance when it comes to student satisfaction.

Finally, insights can be given on the number and types of timetable changes a student experienced. Cancelled or shift lessons can give stress and discomfort among students and can, therefore, influence the student satisfaction negatively. Insights on the changes can be provided per study to show the performance on this aspect.

2.3.4. Teacher satisfaction

Teachers are used to giving lessons offline on location. Preferably they want to give lessons in the same room. Due to COVID-19, a large part of the lessons is given online and part of these online lessons are given from a workplace at home.

A distinction can be made between the different locations that a course can take place:

- Offline, teacher and students are present in a room
- Online, teacher is present in a room but the students are (partly) at home
- Online, teacher as well as students are at home

Preferably, there should be as few as possible changes between the rooms and between lessons at home or on location for a teacher. Moreover, when a teacher is required to provide a part of their lessons from home and a part on location, then it should be prevented that a teacher should travel back and forth from home to the location at an institution.

First, insights can be given on the number of changes home/location per teacher. As said before, these changes can reduce the teacher satisfaction as there need to be travel between these locations. This insight can be given per day to see the amount of location changes for a certain teacher per day of the week.

Secondly, the distribution between lessons at home and courses at location can be shown per teacher. This indicator continues on the previous insight, as instead of the number of changes, a ratio between lesson locations is given. This insight can be given on the total number of lessons of a teacher.

Lastly, insights on the occupancy of teachers can be visualised. More specifically, the total number of teaching hours can be given per week or quartile. This can be of great influence on teacher satisfaction, as a high occupancy means that a teacher has less time to prepare a lesson which can decrease the satisfaction. This insight can be given for different types of teachers (e.g. faculty, specialisation, etc.)

2.3.5. Requested occupation versus actual utilisation

This category outlines the requested occupation of classrooms in comparison with the actual utilisation at students present. To schedule lessons, it is mentioned how many students are expected during a lecture. Based on this input, a suitable classroom is searched. This brings questions with it:

- Are the number of asked seats equal to the actual used number of seats during the first lecture?
- In the case that students can register just before the start of the first lecture: When does the actual number of registrations come close to the estimated number, and does one need to search for another room?
- How is the spread of the number of utilised seats per course, during a period? (hypothesis is that the actual occupation declines after the first college, as there is no compulsory education in the higher forms of education)

Insights can be given on the registrations of a certain course. This is important, as the number of registrations that a course has influences the occupation requested. This insight is only applicable for offline/on location education, as otherwise the occupation of a classroom is of irrelevance. The number of registrations per course will be visualised per period.

Additional insights can be given on the number of seats that were initially asked for a certain course. This indicator goes hand in hand with the number of registrations of a course and, once again, is important to determine the asked classroom occupation.

When a course is scheduled, a classroom is assigned to have a location for this course. This classroom is assigned to this course based on the number of seats asked and the registrations for this course. Insights can be given on the actual capacity of the assigned rooms to a course. The capacity of the assigned rooms should, of course, be larger than the number of registrations.

Finally, to determine the utilisation of a classroom, the actual number of students that are present during a class should be measured/determined. Insights can be given on this number to indicate if the hypothesis mentioned above can be accepted as true (the actual occupation declines after the first college). If this is the case, then smaller classrooms can be assigned to a subject in the course of a period.

2.3.6. Registrations academic year

This category is based on the registration that a new academic year brings with it. The intake of students for an upcoming academic year is important for meaningful insights, such as:

- Capacity of teachers
- Capacity of facilities and rooms
- Efficiency of an education

These insights can lead to decisions, such as attaining more teachers or the lowing of an education budget, which are crucial for any institution. Insights within this category are based on the historical data of institutions.

First, insights can be given on the total number of registrations per education or study. The number of registrations per study will be based on historical data from an academy. As said before, this insight can lead to decisions of teachers, facilities and classrooms.

Second, the number of first-year students that actually started an education can be visualised. Once again, this will be based on historical data and can have meaningful insights. Besides, possible trends can be determined on the number of first-year students that start a study. A potential increasing or decreasing amount of first-year students can show the performance of a study.

Insights can be shown on the number of students not continuing their study after the date of a study advice. Every student will receive a study advice based on their previous study grades and performance. This study advice can result in a change in the number of students that follow a study, as some students might receive negative advice to continue. Possible trends can once again be visualised on the number of students that drop out after they received a study advice based on historical data.

Finally, one can indicate the actual number of registrations for the upcoming academic year. This is crucial to determine the teachers en rooms needed for the upcoming year. This can be shown per study and can be compared with the registrations of the historical data mentioned previously.

2.4. KPIs from literature

Within this section, relevant KPIs related to educational planning are identified with the use of a literature study. Further elaboration and discussion on the KPI identified from the literature is given as well.

2.4.1. Curriculum-based course timetabling

Curriculum-based course timetabling (CB-CTT) is a term identified from various literature that can be relevant for this research. CB-CTT consists of scheduling lectures between teachers and students of a set of courses within a given number of rooms and time periods, satisfying various constraints (Schaerf, 1999). In other words, it is the process of making a suitable timetable for an institution which consists of a complex optimisation problem. During my research I will not deal with making such an optimal timetable, nevertheless the tool I will establish can indicate if changes are possible given a set of resources (e.g. students, teachers, schedules lessons, classrooms, etc.) of an institution. This means that with the use of the tool, it should be clear if a timetable can be constructed with possible changes within the given resources. As said before, the process of CB-CTT deals with numerous constraints that should be satisfied as much as possible to create an optimal timetable. Especially these constraints can help in identifying KPIs that can give insight into the consequences of a decision.

2.4.2. Constraints

First of all, a maximum student load per day is discussed as a constraint for CB-CTT. The constraint states that for each curriculum the number of daily lectures should be within a given range (Bonutti et al., 2010). This implies that lectures that a student has on each day should be in a certain range of time. This constraint is closely related to the number of scheduled course hours after a certain time of day, discussed in Section 2.3.3. Courses should preferably be scheduled within a certain range to satisfy students and insights can be given on the course hours outside this range as a KPI.

Furthermore, curriculum compactness is a constraint for CB-CTT. This constraint implies that it is preferable that the lectures of a curriculum are consecutive, without any empty time period in between (Bettinelli et al., 2015). The constraint is closely related to insights that can be given on the number and distribution of course hours per day for a certain study, mentioned in Section 2.3.3. Idle hours are course hours in between two courses where no lessons are planned. These idle hours should be prevented as much as possible, meaning that lectures should be adjacent to other lectures of the same curriculum on the same day to have an optimal schedule (Bettinelli et al., 2015).

Room stability also is a constraint of CB-CTT and signifies that all lectures of a course should preferably be given in the same room (Bonutti et al., 2010; Bettinelli et al., 2015). It is convenient for teachers as well as students to constantly have a course scheduled in the same classroom. This constraint corresponds to the number of changes home/location per teacher and the number and types of changes that a student experiences, mentioned in Sections 2.3.4 and 2.3.3. respectively. Insights with respect to this constraint can be given on sudden classroom changes and changes between online/ offline lessons of a teacher.

Additionally, room suitability is another important constraint when it comes to CB-CTT. This constraint implies that some rooms may be not suitable for a given course because of the absence of necessary equipment (Bonutti et al., 2010; Bettinelli et al., 2015). Because of this, courses should preferably be given in suitable classrooms. Insights can, therefore, be given on the type of rooms used for each study.

From this, one might be able to see in which types of classrooms a certain study has the most courses given in a quartile and if this complies with the contents of the study.

Finally, the room capacity is a crucial constraint in CB-CTT. The room capacity constraint means that for each lecture, the number of students that attend the course must be less or equal than the number of seats of all the rooms that host its lectures (Bonutti et al., 2010; Bettinelli et al., 2015). This constraint is already taken into account within the data that contains the scheduled lectures of an institution. In addition, this constrain goes hand in hand with the capacity of the assigned rooms to a course, mentioned in Section 2.3.5. However, the capacity of a classroom might change due to a sudden event or decision. Like with the COVID-19 pandemic, people needed to take one and a half meters distance from each other to diminish the spread of the virus. Insights can be given on what the effect on changing (reducing) the current capacity of classrooms is. This can be seen as a what-if scenario and will be discussed further within Section 2.7.

What is relevant with respect to the room capacity constraint from the literature, is that there is a limit of students that can be present at a certain moment in time. This idea complies with the KPI of the number of students on location per time period, discussed in Sections 2.2 and 2.3.1. Insight can be given on the amount of students that are available at a certain time to indicate crowded moments. In addition, if there is a limit on the total amount of students that are allowed to be present at a certain moment within an institution, this KPI can indicate if this limit will be exceeded at a specific moment.

2.5. List of KPIs

Within this section, an overview of all relevant KPIs that were identified related to educational planning is given in the form of a list and can be seen in Table 1. Within this list, KPIs are divided under different categories established in Section 2.3. Moreover, additional comments are given to elaborate more on the KPIs.

Table 1; Overview of KPIs

Category	Key Performance Indicator	Comments
Occupation online/on location	Online/offline lessons (%)	Number of online lessons in comparison with the number of offline (on location) lessons in total of an institution, per quartile.
	Student presence (#)	Number of students present (on location) at an institution, per time period (course hour, day, week, quartile). This can be shown in total or per study or study year.
Occupation per location	Room occupancy (%)	Percentage of the number of book rooms in comparison with the maximum amount of rooms. This can be visualised per classroom type and for different time periods (days, weeks, quartiles).
	Room suitability (%)	Distribution of classrooms used per study per quartile.
Student satisfaction	Maximum student load (#)	Number of scheduled course hours for a study after 17:30hrs per quartile.
	Lesson-free days (#)	Number of days with no lessons per study per quartile or year
	Curriculum compactness (#)	Number of course hours per day per study per quartile or year
	Distribution online/offline (%)	Distribution of online and offline lessons per study per quartile or year.
	Experienced changes (#)	Number and types of course changes a student experienced per study per year.
Teacher satisfaction	Online/offline changes (#)	Number of changes home/on location per teacher per day.
	Online/offline lessons (%)	Distribution between online and offline lessons per teacher per quartile or year.

	Teacher occupancy (#)	Total number of teaching hours given per week or quartile per faculty or specialisation.
Requested occupation versus actual utilisation	Course registrations (#)	Number of course registrations per course.
	Asked seats (#)	Number of seats (places) initially asked per course.
	Capacity assigned classroom (#)	Capacity of the assigned classroom to a course.
	Course students presence (#)	Actual number of students present for a class of a course during a quartile.
Registrations academic year	Registrations (#)	Total number of registrations per study
	First-year students (#)	Total number of first-year students that started per study.
	Dropouts (#)	Number of students not advancing per study after study advice.
	Registrations upcoming year (#)	Actual number of registrations for upcoming academic year per study

2.6. Data for KPIs

When identifying relevant KPIs that are applicable for my research, existing data was taken into account. The already existing data of several institutions was used to understand what KPIs could be realised and created by means of this data. Within this section, first a description of the available data is given. Second the data that is needed to create the KPIs listed in Table 1, is elaborated on per category.

2.6.1. Available data

To provide an overview of what data is needed to create the identified KPIs, it is convenient to first understand what data currently is available and how this data looks like. The data that Senz Interim receives from their clients to give advice or insights to these institutions, first consists of scheduled lessons. Thousands, even tens of thousands of scheduled lessons for an entire academic year are available from institutions. Courses are assigned to different time slots at a specific date. Additionally, numbers of students that are scheduled and a suitable classroom are coupled to the scheduled courses. Next, the study type and study year per scheduled lesson is also provided. Finally, a *teacher* is assigned to make the data of scheduled lessons complete.

Data about the classrooms of institutions is also provided. Here, all the names (codes) of the classrooms are noted as well as the location of these classrooms. Besides, the capacity and type of room is given per classroom.

Data concerning teachers consist of all the teachers that are registered at an institution. The identities of the teachers as well as the courses they can teach are provided. Next, the speciality and faculty of every single teacher can be seen as well.

Schedule changes are also a part of the data that is obtainable and consist of historical data of all different schedule changes that occurred. Multiple types of schedule changes are stated as well as the corresponding study/course and data of when a change in lesson happened.

Finally, data is provided regarding student numbers of an institution. This data contains the registrations for each study at an academy. This means that from this data, the number of students that follow each type of education can be derived.

2.6.2. Category 1: Occupancy online/on location

To create the KPIs for the first category consisting of the occupancy online/on location, data is needed about the scheduled lessons. When it comes to the percentage of online/offline lessons of an academy, the type of lesson for each scheduled lesson should be known. The type of lesson can either be online or on location. Moreover, the date of the scheduled lessons are needed to be able to show this particular KPI per quartile.

For the number of students that are present at an entire institution, the number of students that are scheduled per scheduled lesson is essential to know. In addition, the time period of a scheduled lesson (date, start time and end time) is needed to be able to visualise the number of students that are present per time period. To be able to drill down this KPI even more, data regarding the study type and study year of each scheduled course should be taken into account in order to show the presence of students per study type or study year.

Table 2 provides an overview of the data that is needed to create the KPIs of the first category.

Table 2; Data for Occupancy online/on location

	Online/offline lesson (%)	**Student presence (#)**
Date of scheduled lessons	X	X
Start time lesson		X
End time lesson		X
Type of lesson (online/ on location)	X	
Study type		X
Study year		X
Number of students scheduled		X

2.6.3. Category 2: Occupation per location

To be able to generate the KPIs for the second category, occupation per location, data is mainly needed about the scheduled lessons of an educational institution. The room occupancy first of all needs information concerning the total rooms of an institution that are available. Second, data is needed with respect to book rooms, which can be derived from the scheduled lessons. For this, the classrooms per scheduled lesson are required. Besides, the type of classroom per scheduled lesson should also be known towards making this KPI visible for multiple classroom types. At last, data about the date and time of the scheduled lessons are needed to be able to show this KPI for multiple time periods.

Touching on the distribution of classroom usage, data is needed about the type of classrooms per scheduled lesson. Next, the study type for which a lesson is scheduled should be known in order to show the distribution of classroom usage per study type. Furthermore, the date of the scheduled lessons are requested to envision this KPI per quartile.

Table 3 gives an overview of the data that is required to create the KPIs of the second category.

Table 3; Data for Occupation per location

	Room occupancy (%)	***Room suitability (%)***
Date of scheduled lessons	X	X
Start time lesson	X	
End time lesson	X	
Name of classroom	X	
Type of classroom	X	X
Study type		X
Total classrooms available	X	

2.6.4. Category 3: Student satisfaction

To create the maximum student load indicator, which shows the number of scheduled course hours after 17:30hrs, the start and end times for the scheduled lessons are of importance. These times can indicate if a lesson is actually scheduled after 17:30hrs. The study type per scheduled lesson is essential for this KPI to indicate the performance per type of education. Lastly, the date of the scheduled lessons is required in order to show the maximum student load KPI per quartile.

When it comes to the number and distribution of lesson-free days, the date of the scheduled lessons are crucial. With the date of the scheduled lessons, one is able to see when there are days that students do not have lessons planned. Moreover, the type of study per scheduled lesson is needed to be able to show this KPI per study type.

As regards to the number and distribution of course hours per day (curriculum compactness), the start and end times per scheduled lesson is required. Additionally, the dates of the planned courses are needed towards showing this KPI per day. Finally, the study type for each scheduled lesson is requested to express the curriculum compactness for different types of studies.

In being able to indicate the distribution of online and offline lessons per study type, the type of lesson (online/on location) for each scheduled course is essential. The study type per scheduled lesson is, of course, of importance to show the distribution of this KPI per study type. The date of the scheduled lessons are needed in order to visualise the distribution of online and offline lessons per quartile or year.

The last KPI from this category is concerning the experienced changes that a study type encounters. For this, data regarding the experienced timetable changes is required. First, the type of schedule changes should be known, this can either be a classroom change, teacher change or a course hour change etc. Besides, the study type that encountered each change is required to show the type of course changes per type of education. Finally, the date that a change occurred is essential to show this KPI per time interval.

A summary of the data that is needed to create the KPIs from the third category can be seen in Table 4.

Table 4; Data for Student satisfaction

	Maximum student load (#)	**Lesson-free days (#)**	**Curriculum compactness (#)**	**Distribution online/offline (%)**	**Experienced changes (#)**
Date of scheduled lessons	X	X	X	X	
Start time lesson	X		X		
End time lesson	X		X		
Type of lesson				X	
Study type	X	X	X	X	
Type of changes					X
Study of changes					X
Date of change					X

2.6.5. Category 4: Teacher satisfaction

To generate the number of online/offline lesson changes for teachers, data about the scheduled lessons is needed. First, the type of lesson (online/on location) for each planned course should be known. Moreover, the actual location (room) of the scheduled lessons is of importance. Next, data about the teachers that are assigned to each scheduled course is required. Finally, the date of the scheduled lessons are needed in order to show the number of changes a teacher experiences per day.

The distribution of online/offline lessons per teacher, once again requires the scheduled lessons as an important data source. The type of lesson (online/on location) and teacher of each scheduled lesson are required to create this KPI. The date of the scheduled lessons are needed in being able to show this distribution per quartile or year.

The total number of teaching hours given, first required data about the duration of the scheduled lessons. This duration can be derived from the start and end times per lesson. Second, data about teachers assigned to courses are needed. Additionally, the faculty and specialisation per teacher is required to show this KPI per faculty or specialisation. Finally, the data of the scheduled lessons are needed to visualise this KPI per week or quartile.

Table 5 provides an overview of the data that is needed to generate the relevant KPIs for the fourth category.

Table 5; Data for Teacher satisfaction

	Online/offline changes (#)	Online/offline lessons (%)	Teacher occupancy (#)
Date of scheduled lessons	X	X	X
Start time lesson			X
End time lesson			X
Teacher of lesson	X	X	X
Type of classroom	X	X	
Name of classroom	X		
Specialisation of teacher			X
Faculty of teacher			X

2.6.6. Category 5: Requested occupation versus actual utilisation

To be able to create the number of course registrations, as a KPI within this category, data about student numbers is needed. More specifically, data about the total course registrations as well as the date and course name per registrations is needed to create this KPI.

The number of seats (places) that were initially asked per course is a KPI from which data is directly provided. This KPI takes the requested occupation for each course at an institution into account and can be used as a comparison with the actual utilisation.

For the capacity of the assigned classrooms per course, data about the classrooms of the courses are needed. Besides, the capacity of the classrooms are required to make the data to create this KPI complete.

Finally, the measured number of students that are present per course over time are needed. This can be seen as the actual utilisation and can, thus, be compared with the requested occupation mentioned previously. From these measurements, the date and course are needed to be able to show trends to student utilisation per course.

An overview of the data needed to create the KPIs from this category is given in Table 6.

Table 6; Data for Requested occupation versus actual utilisation

	Course registrations (#)	Asked seats (#)	Capacity assigned classroom (#)	Course students presence (#)
Total course registrations	X			
Date per registration	X			
Course name	X			
Asked seats per course		X		
Classrooms of courses			X	
Capacity of classrooms			X	
Measurements				X

2.6.7. Category 6: Registrations academic year

Towards establishing the number of student registrations, data about the total student registrations of an institutions is needed. Moreover, the study per registration is required to show the number of student registrations per study type. The date of registration is also needed to envision the total registrations at a specific date.

When it comes to indicating the number of first-year students that started an education, data about the total first-year student registrations is required to begin with. Secondly, the study type per registration and date of registration is needed to show the number of first-year students that started a certain study in a specific academic year.

The next KPI is the number of students that are not advancing per study after the disclosure of the study advice per student. For this, data about the total student registrations at the beginning of an academic year as well as data of the study type per registration are needed. Besides, information about the remaining number of students after the study advice are needed.

Finally, for the actual number of registrations for an upcoming academic year per study, historical data is needed about total student registrations of previous years. In addition, the education type per registrations is required as this can help in visualising trends in student numbers per study of an institution.

Table 7 gives an overview of the data needed to create the KPIs from this category.

Table 7; Data for Registrations academic year

	Registrations (#)	**First-year students (#)**	**Students after study advise (#)**	**Registrations upcoming year (#)**
Total student registrations	**X**		**X**	**X**
Study per registration	**X**	**X**	**X**	**X**
Date of registration	**X**	**X**		
Total first-year student registrations		**X**		
Number of dropouts			**X**	

2.7. What-if scenarios

This section is devoted to different what-if scenarios that are applicable for this research. According to Golfarelli et al. (2006) :'what-if analysis can be described as a data intensive simulation whose goal is to inspect the behaviour of a complex system'. In other words, what-if scenarios can be seen as simulations that can show the reaction of a system to a change or decision. What-if scenarios fall under the domain of prescriptive analytics. Prescriptive data analytics prescribes what action can be taken in order to eliminate a future problem (Bekker, 2020). Prescriptive analytics is considered to be the next big step of data analytics, according to Lepenioti et al. (2020), which is ahead of time as it fills a critical gap in business analytics by knowing what intelligent actions can be taken to solve a particular problem. Prescriptive analytics can lead to more optimised decision making and an improvement in business performance (Lepenioti et al., 2020). These what-if scenarios are relevant when it comes to solving the core problem of this research, as what-if scenarios can be used to simulate events or decisions with regard to educational planning. The established BI tool can react and show the consequences of these decisions.

The first what-if scenario has to do with changes within the capacity of classrooms. When the capacity of classrooms changes, the number of students that can be present on location changes as a consequence. This scenario is currently relevant, as less students are allowed to be present in one single classroom due to the COVID-19 pandemic. The consequences of changing the capacity of classrooms will be made visible within the BI tool.

The second what-if scenario deals with the ratio of online/offline lessons given at an institution. Changes within this ratio implies that more or less lessons will be given on location at an academy. As of right now, the majority of lessons are given online due to the pandemic. However, online lessons will most likely still be optional and given in the future. Once again, this scenario will be implemented within the BI tool to show the consequences of changing the online/offline lessons ratio.

Another what-if scenario that can be implemented within the development of the BI tool has to do with student registrations. More specifically, changes within this scenario result in the visualisation of consequences that occur when the number of student registrations next year in total or per study changes. Changes within student registrations can result in more or less first year students and can affect the number of dropouts. This scenarios is relevant, as decisions such as classrooms and teachers that will be assigned to a study type next academic year can be based on the student registrations.

3. Dashboard visualisation

This chapter describes various types of dashboard visualisations and how they can be applied to benefit the proposed KPIs (described in Chapter 2). First, an elaboration is given on the definition and application of dashboards in Section 3.1. Moreover, Section 3.2. outlines various dashboard design guidelines applicable for this research. Section 3.3. describes different dashboard interactivities that can benefit visualisations. Finally, research is conducted on graph transparency, which can be seen in Section 3.4.

3.1. Dashboards

Dashboards are a way of indicating business performance by means of visualisation. A dashboard collects, summarizes and presents information for multiple sources (Yigitbasioglu & Velcu, 2012). Dashboards have major benefits for improving business performance and the development of organisations (Maheshwari & Janssen, 2014). Insights in a quick glance because of a low complexity of displays as well as the support of decision makings are two main benefits of dashboards. Simultaneously, dashboards can be used as a measure for communicating with stakeholders and can have an integration of multiple different perspectives. Dashboards can be seen as an alternative for KPI scorecards, which allow timely tracking of issues and impact regarding KPIs without visualisations and are applicable for my research.

For a dashboard to be useful, it has to contain data related to the business goals of a company (Janes et al., 2013). The development of a dashboard requires the involvement of management and experienced collaborators to show performance on various business goals, in the form of KPIs (see Chapter 2), that can possibly be visualised on a dashboard. Moreover, the development of a dashboard is a continuous process, as an organization, ideally, is always learning (Janes et al., 2013). This implies that dashboards can constantly be updated in order to utilise this type of performance visualisation over longer periods of time.

KPIs can be visualised on a dashboard by means of different types of graphs or charts that allows a user to see business performance in a clear and transparent way. According to Janes et al. (2013), 'the visualisation style you adopt is crucial, it has a huge impact on the acceptance of a dashboard'. Signifying that the effectiveness of a dashboard depends, in most cases, on the way that KPIs are visualised. Additionally, interactivity options (e.g. filtering, zooming in, sorting, etc.) can be incorporated within dashboards to improve visualisations.

There are two different types of dashboards, as stated by Janes et al. (2013), namely dashboard that are meant for pull and push scenarios. In a pull scenario, the user wants a specific piece of information and uses a dashboard to obtain this (Janes et al., 2013). Within this scenario, there should often be more possibilities to explore data that is visualised. However, when it comes to the push scenario, the dashboard has to be designed so that important data is pushed to the users (Janes et al., 2013). Meaning that the dashboard should capture the attention of users and inform them. Dashboards that are meant for push scenarios can inform users to unexpected or unforeseen situations.

Consequences of a decision within the domain of educational planning can clearly be visualised with the use of a dashboard. Because of this, dashboards, more specifically; push dashboards, will be used during my research in order to solve the chosen core problem. This is because a user should be able to see the feasibility of an educational planning.

3.2. Design guidelines

This section describes relevant dashboard design guidelines or principles for this research based on literature. Dashboard guidelines are important for the effectiveness and user-friendliness of a dashboard. The guidelines discussed within this section are, first, based on the paper of Young and Kitchin (2020). This paper gives an examination of four city dashboards to identify guidelines for producing a dashboard system for Dublin, Ireland (Young & Kitchin, 2020). Moreover, the work of Maheshwari and Janssen (2014) about the derivation of principles for the design and development of dashboards is considered. A distinction is made between, in total, six different design guidelines that are applicable for this research. An overview of all guidelines with a brief description is provided and can be seen in Table B.1 within Appendix B.

3.2.1. Navigation

The first dashboard guideline has to do with the navigation on the dashboard. According to Young and Kitchin (2020, p.16), dashboards should 'implement logical navigation patterns and menus, so users can explore data with confidence and quickly trance their progress throughout the dashboard hierarchy'. Thus, there should be a clear path visible that guides a user toward different information that is represented on a dashboard. Proper dashboard navigation can reduce complexity and create a clear overview of the data that is being visualised. This can help in a better understanding and interpretation between users.

In addition, there should be a clear navigation between multiple connected dashboards, zooming functions and other interactivity options (discussed in Section 3.3.). This can be done by means of facilitated menu functions, for instance. This way, if a user takes a wrong turn on the dashboard, these functions allow users to correct their unintended actions (Young & Kitchin, 2020). This suggests that proper dashboard navigation also stimulates that user-friendliness of a dashboard.

3.2.2. Style

The second dashboard guideline deals with the style of the dashboard. The overall look and feel of a dashboard should be representative of a company and should be applied consistently to help construct familiarity and confidence as well as improving the overall user experience (Young & Kitchin, 2020). In other words, there should be no ambiguity in the look and feel of the dashboard. Meaning that, preferably, all pages and themes should remain the same throughout different areas of the dashboard. When looking at this research, the colouring of Senz Interim can be seen as a style that is related to the company. Moreover, a logo of the company can also be implemented on the dashboard to create even more familiarity with the company to fulfil this dashboard guideline.

3.2.3. Linking items

Key Performance Indicators on a dashboard are often closely connected to each other. Maheshwari and Janssen (2014) state that linking the KPIs of a dashboard (dashboard items) is essential in effective visualization, representation of the missing information, and interpretation support. Linking KPIs, therefore, requires understanding of organisational strategies, viewpoints, business processes, indirect effects, decision support systems, and managerial priorities (Maheshwari & Janssen, 2014).

The established KPIs seen in Section 2.3. are linked to each other by means of six different categories. The KPIs of each category can be grouped and linked together separately for an effective dashboard design, according to the dashboard guideline mentioned within section,

3.2.4. Data types

For the dashboard that I will make during my research and to create the KPIs, different data types in terms of real-time data and historical data will be used. A dashboard guideline mentioned by Young and Kitchin (2020) states that both real-time and historic data should be arranged logically and grouped thematically on a dashboard.

Most of the data, such as the scheduled lessons, classrooms and teachers, can be seen as real-time data of an institution. Nevertheless, the category "Registrations academic year" (Section 2.3.6. and Section 2.6.7.) includes historical data of student registrations at an institution and should, according to the design guideline of data types, be grouped separately. This historical data can be further used for development and benchmarking. Maheshwari and Janssen (2014) state that along with systematically monitoring, analysing, and measuring the performance, dashboards should include information over time periods for learning and growth. The historical data on registrations can be used for learning and growth, as it can help in showing trends and predicting the number of students per type of education for the upcoming years. This on its own can influence the teachers and classrooms needed for the upcoming year(s).

3.2.5. Communication

Arguably the most important aspect of a dashboard is the communication of indicators that can clearly bring a message on the status of the business performance. The contents should be clear and understandable for the user of a dashboard. One should use effective language and appropriate visualisations on a dashboard to communicate meaning across multiple platforms (Young & Kitchin, 2020). Effective language can quickly bring messages to users about business performance. When it comes to the visualisation aspect of a dashboard, Maheshwari and Janssen (2014) state that dashboards enable the use of charts, colours, graphs, pictograms, bars, numbers etc. to visually communicate information for monitoring, analysing, and assessing the performance at a glance. Appropriate visualisation of relevant, precise and vivid data is for great importance (Maheshwari & Janssen, 2014). Another communication guideline, according to Sedrakyan et al (2019), is that visualizations on a dashboard should be kept at high abstraction levels. Interactivity options and filters should be applied to zoom from high level visual views into more specific granular linked views (Sedrakyan et al., 2019).

Colouring can help users in the interpretation of urgent problems or matters on a dashboard. Janes et al. (2013) make a distinction between three different colour indicators for dashboards, namely red, yellow and green indicators. Where red indicators identify that the problem is serious, and that immediate action is required (Janes et al., 2013). Yellow indicators visualise that some action is required soon, whereas green indicators inform that everything works fine (Janes et al., 2013). Furthermore, transparent graph types can also stimulate the communication on a dashboard. This aspect will be further explained within Section 3.4.

Additionally, Young and Kitchin (2020) describe the importance of different dashboard sheets. As different dashboard pages can serve different users, therefore, understand your audience and focus on communicating data across multiple pages, platforms, and modalities accordingly (Young & Kitchin, 2020). This relates to two dashboard guidelines mentioned previously about “Linking items” and “Data types”. This is because different sections or groups to effectively show the KPIs can be created with the use of different dashboard pages.

A symmetrical layout and proper typography are important for correct dashboard interpretation and communication. Bhatt et al. (2017) addresses some interesting and relevant guidelines with respect to this, which can be seen in Table 8.

Table 8; Layout and typography guidelines according to Bhatt et al. (2017).

Topic	Guideline	Description
Layout	Aligning object	X-axis and Y-axis of objects (charts, tables, etc.) next to each other should be exactly same.
	Space in-between objects	Try to leave consistent space between objects and to the edge of the screen, this avoids user claustrophobia and delineates objects nicely.
	Object types	Objects of the same type should be placed at the same location on every sheet of the dashboard.
	Space utilisation	All the space given on the page needs to be utilised appropriately; it should not look too clustered and on the same side there should not be empty spaces between the objects or in the corners of the page.
Typology	Headers	Headers include titles, name of the organization and some major sections of the work which needs to be highlighted. Font size of the headers should be significantly larger.

	Messages	Messages (e.g. pop-up or error messages) describe additional things the reader should be aware of. These should fade into the background unless you call attention to them.
	Emphasis text	Emphasis text is to be used where you want to grab the reader's attention. Text should be under italics and placed with asterisk symbols.

3.2.6. Possibilities and conjectures

The last dashboard guideline is about exercising possibilities and conjectures. As of right now, most dashboards mainly focus on reporting and visualizing of the ongoing operations and business processes. However, according to Maheshwari and Janssen (2014): 'Dashboards should also enable organizations to analyse different scenarios and future conjectures for measuring, benchmarking, and improving organizational settings'. This dashboard guideline is relevant as it goes hand in hand with prescriptive data analysis. During this research, several what-if scenarios will be used in order to visualise the consequences of decisions, as can be seen in Section 2.7. These scenarios enable dashboard users to do more than just seeing the current or historical business performance. This is because, the outcomes different scenarios can be analysed by users to be able to react proactive to changes, for instance.

3.3. Interactivities

Dashboard interactivities or features allow users to interact with data that is visualised on a dashboard. These interactivities can stimulate the user-friendliness and understanding of dashboards, resulting in more informed decision making. This section outlines relevant dashboard interactivities that are supported in a wide range of different BI tools, found within various literature. More specifically, four different dashboard interactivities will be discussed that will benefit any KPI dashboard, namely drill down, filtering, scenario analysis and information tooltips.

3.3.1. Drill down

The drill down interactivity option enables users to see data and information that is visualised in more detail. The drill down feature can be seen as a point and click interactivity that allows users to drill down information to obtain further details on various performance indicators (Nadj et al., 2020; Resnick, 2003). In other words, this dashboard interactivity enables users to add more levels to charts or graphs, by simply clicking on the visualisations. The drill down feature is highly desirable, as it would allow dashboard users to slice and dice data for a more detailed analysis, where in its absence, users might be forced to switch back and forth between various applications (Velcu-Laitinen & Yigitbasioglu, 2012; Yigitbasioglu & Velcu, 2012). This might disrupt and influence the decision making process.

The drill down feature is chart specific, meaning that a user is able to drill down the data of one chart at a time. The drill down interactivity option can be seen as a zoom option, as a user is able to zoom into more detailed information for an indicator that is visualised. Drill down features are useful for this research, as more detail per KPI (e.g. time periods, study types, etc.) can be shown with the use of this interactivity. The opposite of the drill-down feature is the roll up interactivity, which makes the visualised data less detailed whilst interacting with a graph or chart (Nadj et al., 2020).

An alternative for the drill down interactivities, which is fairly similar, are drill-throughs interactivities. Drill-throughs are interactive dashboard software that can show additional and more detailed information for a KPI as well. However, this can be done without overcrowding a dashboard (Durcevic, 2020). This is because, a more detailed visualisation of data is shown as a separate pop-up screen with the use of a drill-through, whilst a drill down interactivity can be only executed while still on the same main dashboard.

3.3.2. Filtering

Filtering can be seen as another interactivity option that is commonly used and can be applied to dashboards. This dashboard interactivity allows users to utilize the dimensions of the charts and graphs of a dashboard as temporary filter values (Durcevic, 2020). When it comes to this thesis, there often is a distinction between different time periods, study years and type of studies within the KPIs (see Chapter 2). These variables can be seen as relevant dimensions for which filtering can be applied on a dashboard. Moreover, Nadj et al. (2020, p.9) about the importance of filtering state that 'filtering is another valuable functional feature, since it enables users to not only sort for relevant information but also identify hidden data relationships'.

The filtering feature, similar to drill down interactivities, can simply be applied by clicking the filters that a user wants to enable. Filtering can be applied for a data set of a specific KPI as well as for all the KPIs that share the same dimensions on an entire dashboard sheet. Filtering allows users to find data more specifically, in comparison with the drill down feature mentioned in Section 3.3.1. This is because, users themselves can perform target searches by filtering on specific dimensions.

3.3.3. Scenario analysis

Scenario analysis is the next dashboard interactivity option that can benefit the dashboard usage. A scenario analysis can be described as a decision support tool that a user can utilise to see how changes in a certain variable impact other variables (Velcu-Laitinen & Yigitbasioglu, 2012). During this research, what-if scenarios are relevant when it comes to this interactivity option. Section 2.7. is dedicated to the what-if scenarios that are applicable for this research and elaborates more on this interactivity option.

Within such a what-if scenario, users are able to modify the data, constraints or objectives of an optimization problem (Nadj et al., 2020). This can simply be done by adding several interactive sliders on a dashboard page, from which users are able to change several variables by changing the position of the what-if slider(s). Once a scenario is applied, one is able to see the effect by analysing the changes within the KPIs that are visualised on the dashboard.

3.3.4. Information tooltips

The last dashboard interactivity that can benefit the KPI visualisations are information tooltips. Information tooltips enable specific explanations and additional information to the visualisations on dashboard to users (Durcevic, 2020). The tooltips (i.e. detailed messages) are triggered once a user hovers their mouse over an icon next to an indicator, making it interactive for users. This type of dashboard interactivity stimulates the user-friendliness of dashboards, as it can help in a better understanding and interpretation of indicators that are being visualised.

Additionally, dashboard alters or notifications that pop-up are very functional and useful when it comes to providing information. Real time notifications and alerts are necessary for user awareness, since corrective actions can be triggered or recommended as soon as the measures deviate from predefined targets or when measures no longer meet critical thresholds (Velcu-Laitinen & Yigitbasioglu, 2012; Nadj et al., 2020). Alerts to make users aware of possible problems can be relatively easily implemented through the use of distinct colours, flashing and/or even audio signals (Velcu-Laitinen & Yigitbasioglu, 2012). These dashboard notifications can be applicable if a certain situation within the educational planning of an institution is far from desirable, for instance.

3.4. Graph transparency

The use of transparent graphs or charts is important, as this can help users with the interpretation of the visualisations. There exist a wide range of graph types that are all able to visualise indicators on dashboard. This section of my research describes the most transparent graph or chart types that are applicable for this research, based on systematic literature review. An overview of the mentioned graph types can be seen in Table C.1 within Appendix C.

3.4.1. Large amounts of data

The type of graph that can give the most transparency depends on the amount of data that one wants to visualise. For large amounts of data, scatter plots are often used as transparent graphs. Kanjanabose et al. (2015) state that a parallel coordinate plot results in the best way of data representation in comparison with a normal (simple) scatter plot. Conversely, Abi Akle et al. (2019) argue that a scatter plot matrix is the most effective way of representing large amounts of data, in comparison with the previously mentioned parallel coordinate plot and simple scatter plot.

Moreover, radar charts are described as a way of effectively representing large amounts of data (Dy et al., 2021). Additionally, heat maps are described as an option for large amounts of data (Dy et al., 2021; Goldberg & Helfmann, 2014). A comparison on the accuracy and decision time was done by Dy et al. (2021) between four different charts mentioned before, namely the scatter plot matrix, parallel coordinate plot, heat maps and radar charts. The accuracy relates to how well a graph is interpreted, whereas the decision time (response time) relates to the time it takes to understand the graph. Within this study, the heat maps came out on top (parallel coordinate plot second, radar chart third and scatter plot matrix last), as heat maps display data matrices in a compact area which makes identifying patterns or comparisons easier (Dy et al., 2021).

Another mentioned chart that is able to represent large amounts of data in a transparent way is the tree map (Chynal & Sobecki, 2016; Von Landesberger et al., 2011). According to Chynal & Sobecki (2016): "large datasets are most clearly presented within a tree map".

Table 9; Comparison of transparency between large data graph types, based on literature research. From very transparent (++, green) to not transparent (--. red).

Graph type (large amounts of data)	Transparency
Heat map	++
Tree map	++
Parallel coordinate plot	+
Radar chart	+/-
Scatter plot matrix	-
Simple scatter plot	--

3.4.2. Limited amounts of data

When it comes to visualising smaller amounts of data, four different types of graphs can be identified, namely line graphs, bar graphs, pie charts and combined charts. A lot of comparisons were done within the selected articles based on these types of graphs. When comparing these graphs, a pie chart often gave the lowest response time of participants (Gillan et al., 1998; Hink et al., 1998), especially when multiple visual elements were included (Gillan et al., 1998; Chynal & Sobecki, 2016). However, a pie chart showed poor accuracy when it comes to specific numerical values and trends (Hink et al., 1998).

When it comes to line and bar graphs, these were often compared with each other. Hink et al. (1998) states that these types of graphs show the best speed-accuracy trade-off. A bar graph (bar chart as well as a column chart) is often more effective when it comes to response time of participants (Acartürk, 2014; Shaheen et al., 2019; Goldberg & Helfmann, 2014). Generally speaking bar graphs are more effective for comparisons of multiple values (Chynal & Sobecki, 2016; Hink et al., 1998). Whilst line graphs are most effective when it comes to numerical values and finding trends (Chynal & Sobecki, 2016; Hink et al., 1998). Sedrakyan et al. (2019) state that line charts are known to convey changes for multiple datasets over time by connecting data along an interval scale, which will show how data changes at equal intervals of time. This implies that line charts can support awareness of progress during specified periods of time.

Combined charts (bar and line) are also a solid option for representing limited amounts of data. These types of graphs are very effective for comparisons of two measures (Chynal & Sobecki, 2016). Hink et al. (1998) state that combined charts result in a longer response time, but a higher accuracy than singular bar or line graphs.

Overall, the type of graph that can give the most transparency when it comes to smaller amounts of data, depends on the purpose of the visualisation. Line graphs are able to transparently visualise numerical values and trends, whereas pie charts show poor accuracy herein. Bar graphs are most effective for comparisons of multiple values. Pie charts are understood quickly when visualising multiple elements. Finally, combined charts show high accuracy among users and are effective for comparisons.

4. Solution design

This chapter describes the solution design for this research. First, a suitable BI tool needs to be found to create this solution design. Section 4.1. outlines the method that is used for selecting the most suitable BI tool. Section 4.2. discusses several criteria used within the AHP that a tool preferably needs to satisfy. Section 4.3. gives a description of all decision alternatives that are taken into account.

4.1. Analytical Hierarchy Process

During this research, the Analytical Hierarchy Process (AHP) is used in order to find the most suitable BI tool for the solution design of this thesis. AHP, founded and developed by Saaty (1980), can be seen as a strong tool for multi-criteria decision making that has been applied to large-scale problems in past research (Taherdoost, 2017). This is because this decision analysis technique is able to evaluate complex multi-attribute alternatives among one or more decision-makers (Emrouznejad & Marra, 2017). Moreover, as AHP allows the inclusion of subjective factors, it is considered as an advancement compared to other decision-making methods available (Emrouznejad & Marra, 2017).

The general idea behind AHP is that multiple decision alternatives are ranked based on how well the alternatives score on every criteria that is established by the decision maker (Figure 5). Alternatives are ranked by means of pairwise comparisons with the other alternatives for every single criteria, based on the choices of the decision maker(s). Additionally, pairwise comparisons are conducted among the criterion in order to determine the weights that account for each criteria. Implying that one criteria can be of greater importance for a decision maker than the other(s). Finally, the most optimal decision alternative can be calculated. An overview of all the steps taken within the AHP to find the most suitable alternative can be seen in Appendix D.

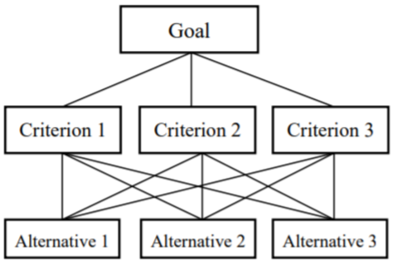

Figure 5; AHP (Taherdoost, 2017)

4.2. Decision criteria

This section gives a description of all the criteria that are applicable in selecting the optimal BI tool. In total, four criteria are taken into account, namely; visualisation, cost, user-friendliness and mobile app. The possibility for a tool to extract, transform and load the data (ETL) is not taken into consideration. The main reason for this is that Senz Interim aims for the development of a data warehouse/middleware system for the long term where the ETL process will already be conducted. The criteria for the BI tool are established with the use of communication and interviews with in total four consultants of Senz Interim. All the criteria described are also given a certain weight, the results of this can be seen in Appendix D.

4.2.1. Visualisation

The first criteria that is used within the AHP is regarding the visualisation possibilities of the BI tools. Visualisation is a very important aspect of every dashboard and a BI tool will be advantageous if there are extensive visualisation options. Strong visualisations helps with a good interpretation and communication of indicators that are shown on a dashboard (see Section 3.2.5.). Within this criteria, the BI tool alternatives will be assessed on graph options, layout and interactions for example. Moreover, features that are able to improve the dashboard visualisation or communication, such as conditional formatting, will be taken into consideration.

4.2.2. Cost

The second criteria to be taken into account is related to the costs of the BI tool alternatives. A decision alternative will be advantageous if low costs are involved when using or purchasing the tool. Senz Interim states that a certain budget will be available for establishing and maintaining the BI tool. However a tool that is very expensive will preferably not be supported if there is a cheaper alternative that is quite similar in terms of the other criteria.

4.2.3. User-friendliness

The user-friendliness of the BI tool can be seen as another criteria used in the AHP. The user-friendliness criteria, first, contains the ease of use for the developer that will be using the tool. Within this criteria, aspects such as the programming languages of the tools or experience that is currently already within the business regarding the use of a certain tool will be considered. Moreover, the ease of use for clients will be taken into account within the user-friendliness criteria. The BI tool should, for example, preferably be able to support multiple clients and add other users with ease that can view the established dashboard(s).

4.2.4. Mobile app

The last decision criteria is the possibility to view the indicators on a dashboard online or via a mobile device/app. This can lead to a high level of accessibility, as users are able to view their educational planning performance with ease with a mobile application. This is a criteria mentioned by Senz Interim, as they value this option for themselves and their customers.

4.3. Decision alternatives

This section outlines all the decision alternatives that are taken into account for the selection of the most suitable BI tool for this research. In total, five BI tools are considered, namely Power BI, Tableau, Qlik, SSRS and Excel. The alternatives that are discussed are chosen because of personal experience, literature and recommendations from consultants.

4.3.1. Power BI

The first BI tool that is considered in the AHP is named Power BI. Developed by Microsoft, Power BI is a modern and graphical cloud-based tool that is able to create analytics and dashboards out of data with the use of business intelligence (Microsoft, 2021). When it comes to visualisation, Power BI is a solid option and can offer some interesting features. Many dashboard and layout options are strong points of this alternative (HSO, 2019). Power BI, however, is lacking regarding analysing and drilling down large amounts of data points. The cost of Power BI is relatively low on the market, though can rise significantly when the tool needs to be used within large enterprises (Microsoft, n.d.).

The user-friendliness of Power BI is high when it comes to the ease of visualisations. Users can apply a drag-and-drop capability to create suitable graphs and charts easily from large data sets to generate reports (HSO, 2019). The main issue within this criteria lies in the programming language used within Power BI. According to two consultants of Senz Interim, the language within Power BI named DAX is very specific, quite difficult to learn and is not applicable everywhere. There is a mobile app available on all platforms where users can show and interact with visualisations (HSO, 2019).

4.3.2. Tableau

Tableau is the second BI tool that is taken into account as an alternative in the AHP. Tableau is a very mature tool that is one of the most commonly known BI tools within the market. The perspective of reporting in Tableau is interactive visualisations, meaning that especially the data visualisations are a strong point that distinguishes Tableau from their competition (HSO, 2019). This is because Tableau offers a variety of extensive data visualisation options that can help people in seeing and understanding the data by means of dashboards. Moreover, drag-and-drop visualisation formats within Tableau result in a high level of user-friendliness (HSO, 2019). An addition to this is that, personally, I used Tableau beforehand which was a pleasant experience.

That Tableau is a mature tool with many visualisation features can be seen within the price of the tool, as the purchasing cost for a single user is one of the highest within the market. Furthermore, the cost of Tableau will rise significantly for it to be used on an enterprise level where multiple users are incorporated that can potentially use all features and extra options Tableau has to offer (Tableau, n.d.-a). A mobile application is provided within this BI tool, namely Tableau Mobile. Tableau Mobile can include interactive visualisations that users are able to access online via desktop or mobile app or even offline (Tableau, n.d.-b; HSO, 2019).

4.3.3. Qlik

Qlik, also known as Qlik Sense, is a well-known tool that enables users to create interactive reports and dashboards by means of business intelligence. With the use of the associative analytics engine, integrated within Qlik, the tool can help users to select suitable visualisations. Because of this, Qlik can be seen as the third decision alternative for this research. Qlik offers a broad set of visualisations, storytelling features and can provide high-end analytical abilities with the use of dashboards (HSO, 2019). The visualisation abilities within Qlik can be seen as the top of the market. This comes along with a relatively high price tag, as Qlik is within the high-end of pricing in comparison with most of the competition. The main reason for this is that in order to use additional features or advanced options within Qlik, the prices rise significantly (HSO, 2019).

The ease of use of Qlik is of a high level. There are loads of available features within the tool that can stimulate this criteria. In addition, Qlik is able to cope with large amounts of data so that users can create extensive visualisations fairly easily. Like most of their competitors, Qlik provides a mobile app. The app named Qlik Sense Mobile allows users to interact and explore data with an optimized native app that is available on all platforms. The mobile app provides interactive data visualisations offline as well (Qlik, 2021; HSO, 2019).

4.3.4. SSRS

SQL Server Reporting Services (SSRS) is a server-based business reporting software that will be considered as an alternative during the AHP. Created by Microsoft, SSRS is an advanced BI tool that is able to create and export various reports or dashboards in a wide range of formats with the use of SQL. In general, the perspective of SSRS reporting is data reporting or visualisation with simple charting (Data Flair, 2019). Because of this, SSRS lacks modern interactive charts visualisations. There are many visualisation options that can be realised within the tool and the basic features that SSRS offers are relatively easy to learn and understand (Meidinger, 2018). However, a fair amount of advanced coding knowledge is necessary in order to create advanced dashboards (Data Flair, 2019). This implies that the ease of use for developers is not very high. Moreover, the enabling of adding more users or clients to view the created dashboard(s) is not convenient when using SSRS, according to the experience of a consultant of Senz Interim.

The cost of using SSRS depend on the type and request of the company applicable. However, generally speaking the costs when purchasing SSRS for enterprise usage is quite high. The main reason for this is that it is necessary to buy a SQL Server license in order to use SSRS to its full extent (Meidinger, 2018). A mobile app is available for this decision alternative. Within the same application that is developed by Microsoft for Power BI, users are able to create interactive mobile reports and can view visualisations (Microsoft, 2019).

4.3.5. Excel

The final decision alternative for the AHP is Excel. Excel is a spreadsheet program that is established by Microsoft. Excel is widely applied within the business world and can carry out many calculations with ease (Meidinger, 2018). Besides, one is able to create a dashboard within Excel with the use of various graphing tools and tables that are available within the program (Meidinger, 2018). However, Excel is no specialised business intelligence tool, meaning that it has basic and straightforward visualisation options with no special interactivity features. One is able to program within Excel with the use of Visual Basic for Applications (VBA), which can realise the creation of personal interactivity features (PNRao, 2017). The use of VBA is not difficult, though is often inefficient and may cause large delays in the calculation of formulas and in the generation of visualisations if large data sets are used, based on personal experience. This makes the user-friendliness of this alternative to be relatively low.

The pricing of Microsoft Excel is favourable as it is quite low on a monthly or yearly basis (Capterra, 2020). Moreover, Excel is included within Microsoft Office which is widely available and accessible among users. A mobile app is available for Excel, but the functioning often is not optimal. The main reason for this is that Excel is not able to run a VBA code on the mobile application. This implies that no proper dashboard visualisations with interactions and calculations can take place on a mobile app.

4.4. Results AHP

This section describes the main results of the execution of the AHP. The stepwise approach of the entire process for selecting the most suitable BI tool can be found in Appendix D.

The decision criteria stated in Section 4.2. are compared pairwise based on the input of two consultants as well as my own opinion. The rounded average results of these comparisons create weights for the criteria. The weights for each criteria can be seen in Table 10.

Table 10; Weights per criteria for the AHP

Criteria	Weight
Visualisation	0,534204
Cost	0,11768
User-frienliness	0,290539
Mobile app	0,057577

The decision alternatives are compared to each other for every criteria. The preferences of a certain tool in comparisons with another for each criteria are based on the findings stated in Section 4.3. A preference matrix is established based on these pairwise comparisons, which shows the preference for a certain BI tool for every criteria. The preference matrix can be seen in Table 11. The overall ranking for the BI tools can be made with the use of the preference matrix and the criteria weights, which is shown in Table 12. From this, one can conclude that Tableau is the most suitable BI tool for this research and will, therefore, be used in the following steps of this research.

Table 11; Preference matrix AHP

	Criterion			
	Visualisations	Cost	User-frienliness	Mobile app
Power BI	0,1922	0,1698	0,1545	0,2381
Tableau	0,3249	0,0620	0,3991	0,2381
Qlik	0,3249	0,0999	0,3025	0,2381
SSRS	0,1120	0,0999	0,0889	0,2381
Excel	0,0459	0,5683	0,0550	0,0476

Table 12; Overall ranking BI tools AHP

BI tool	Score
Power BI	0,18127
Tableau	0,31055
Qlik	0,28693
SSRS	0,11113
Excel	0,11012

Finally, the last step of the AHP is the consistency check. A consistency check is an important step of the AHP which checks the validity of the conducted pairwise comparisons. The consistency ratios (CR) are calculated for all five pairwise comparisons that are created in the AHP and can be seen in Table 13. The degree of consistency is satisfactory if $CR < 0,10$ (Taherdoost, 2017). This is the case for all pairwise comparisons, meaning that the AHP applied for this research is consistent and valid.

Table 13; Consistency check AHP

	CR
Criterion	0,0326
Visualisation	0,0094
Cost	0,0226
User-friendliness	0,0341
Mobile app	0

5. Implementation

This chapter outlines the implementation part of my research, where the results of this research are stated. First, the data that acts as the input for the BI tool is described in Section 5.1. Moreover, the results of the KPI visualisations of this research are discussed and can be seen in Section 5.2.

5.1. Input for the BI tool

It is worth mentioning that not every currently available data from various institutions (described in Section 2.6.1.) can be used for the development and input for the BI tool. The main reason for this is that the data coming from institutions may only be used for giving advice and the development of software which is agreed upon in a contract. Data from one anonymous educational institution is made available for this research and will act as the input for the BI tool, in compliance with this institution. The data available consists of the scheduled lessons for multiple studies for two academic years (2019-2020 and 2020-2021). Furthermore, the data regarding classrooms from this institution is also made available. However, data regarding teachers of this institution cannot act as input for the BI tool due to privacy related issues, signifying that the KPIs regarding the teacher satisfaction category will not be visualised. Both the data regarding scheduled lessons and classrooms is anonymized, meaning that study types and classroom names will not be relatable to the institution the data is originating from.

Dummy data has been made from schedule changes, classroom occupancies versus utilisations and student registrations to be able to visualise the KPIs regarding these topics, as the original data could not act as input for the BI tool. The dummy data is randomly or manually generated to be able to get realistic data that can show what visualisations and insights can be made if this data is made available in the near future.

5.2. Results of visualisations

Within this section, the results of the KPI visualisations that have been made with Tableau (see Section 4.4.) are globally discussed for each dashboard sheet. Besides, some examples are given to indicate the values of the visualisation that were made. A more detailed description of every visualisation and drill down option within the BI tool can be seen in the manual of the tool within Appendix E.

5.2.1. Sheet 'Occupancy online/ on location'

On this dashboard sheet, seen in Figure 6, the KPIs within the category occupancy online/ on location are visualised. First of all, the percentage of online lessons of the entire institution is stated. Moreover, the total students that are present during various block hours are visualised by means of a tree map. A block hour consists of two course hours, meaning that the third (most crowded) block hour consists of course hours 5 and 6. Filters on academic year and period (quartile) can be applied on the KPIs on this dashboard sheet and can be seen in an orange box at the top right of the sheet. Two what-if scenarios can affect the visualisations on this dashboard and can be seen under the filters. First of all, the room capacity can decrease according to a percentage. Besides, the number of online lessons can increase in percentage of offline (on location) lessons that change to online lessons. A drill down option is available for the total student presence KPI, which is elaborated on in Appendix E.

A value with regard to this dashboard sheet is that one is able to identify at what situation the total student presence is exceeding the norm. For example, a regulation could be that there can be a maximum of 50.000 students that can be present during an entire period due to the COVID-19 pandemic. Previously, no insights were given on how to solve this. However, with the use of the developed BI tool, one is able to change the number of online lessons as well as the room capacities to reduce the total student presence. Ultimately, a desired situation can be research with a combination of decreasing the room capacities and increasing the online lessons, were no more than 50.000 students will be present during a block hour in an entire period.

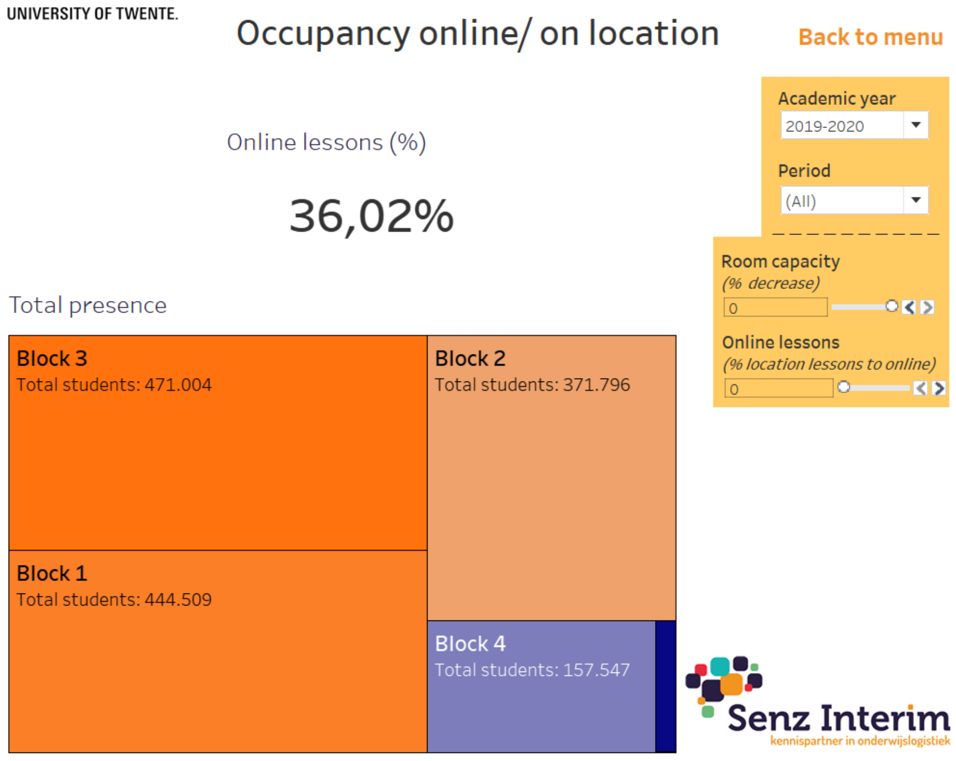

Figure 6; Dashboard occupancy online/ on location

5.2.2. Sheet 'Occupation per location'

The second dashboard sheet visualises the KPIs mentioned within the category occupation per location with two additional indicators and can be seen in Figure 7. The top left graph on the dashboard is an additional KPI which shows the number of scheduled lessons per course hour (room occupancies) for the buildings with the corresponding room type filter in a line graph. There is a drill down possibility for this visualisation, which is explained in Appendix E. The room occupancy KPI is visualised in a tree map in the bottom left of the sheet and shows the number and percentage of scheduled lessons per classroom of the corresponding room type filter value. The room suitability is visualised in a pie chart on the dashboard and shows the distribution of classroom types that are used per study or time period. Finally, the bottom right bar chart is another additional KPI that shows the average room occupancies for all of the different classroom types. A drill down option is available on this chart, which is elaborated on in Appendix E. A user is able to filter on different academic years and periods that affect the whole dashboard. Moreover, one is able to filter on different studies that impact the room suitability KPI. Besides, a room type filter can be applied that impacts the line graph and tree map on the left, as the insights for buildings and classrooms of different room types can be seen. Finally, the two what-if scenarios that were on the previous dashboard sheet are incorporated in this dashboard as well. Changing these scenarios can show the impact on the KPIs that are visualised.

An example with regard to the value of the visualisation of the room occupancies line graph, is that an institution does not want to have more than 300 lessons scheduled within a certain building during a course hour in a period. Where previously no insights could be given related to this issue, one is clearly able to see when the number of scheduled lessons per building exceeds the norm. Additionally, one is able to change the online lessons scenario to get insight at what situation this issue will be solved.

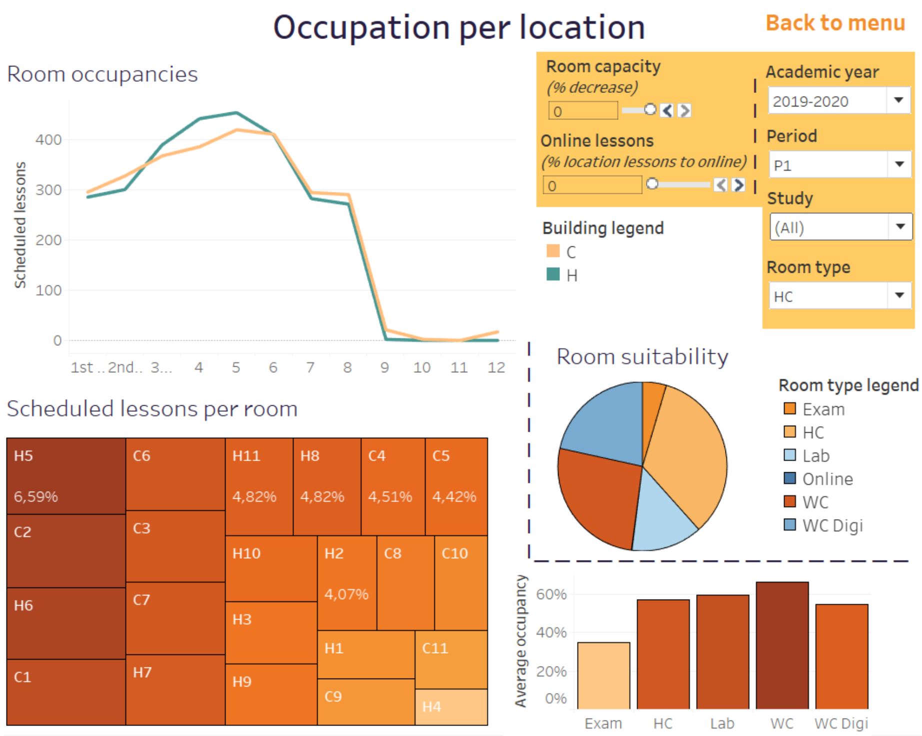

Figure 7; Dashboard occupation per location

5.2.3. Sheet 'Student satisfaction'

The student satisfaction dashboard sheet shows all of the KPIs within the category student satisfaction, seen in Figure 8. This dashboard, first, shows numbers regarding the percentage of online lessons, the average lessons per day (curriculum compactness) and the lesson free days. These KPIs can be visualised among multiple academic years, periods, studies and study years. Moreover, the maximum student load is visualised by means of a bar chart in the top left and shows the number of lessons after 17:30hrs per period and varies with the filters mentioned previously. Finally, the number of experienced schedule changes is visualised with a pie chart and also gets affected by a change in the filters. The what-if scenario of an increase in the percentage of offline lessons put online is also implemented within this dashboard and solely impacts the percentage of online lessons.

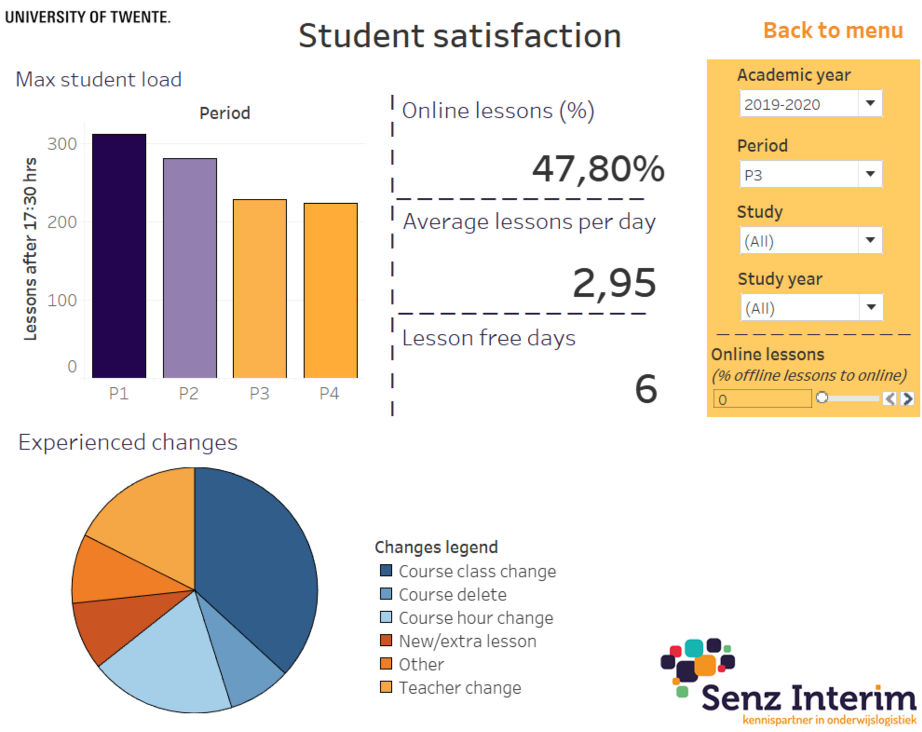

Figure 8; Dashboard student satisfaction

5.2.4. Sheet 'Requested occupation versus actual utilisation'

This dashboard sheet visualises the KPIs within the category requested occupation versus actual utilisation and is shown in Figure 9. First of all, the student presence per course number is visualised for three different years with the use of a line graph for multiple courses. Within this KPI, one is able to get insight into trends regarding the number of students that are present during the timespan of a course. Furthermore, the number of course registrations, asked seats and capacity of the assigned classroom are visualised in a bar chart at the bottom of the dashboard. This is once again shown of three years and can be shown for multiple courses once filtered.

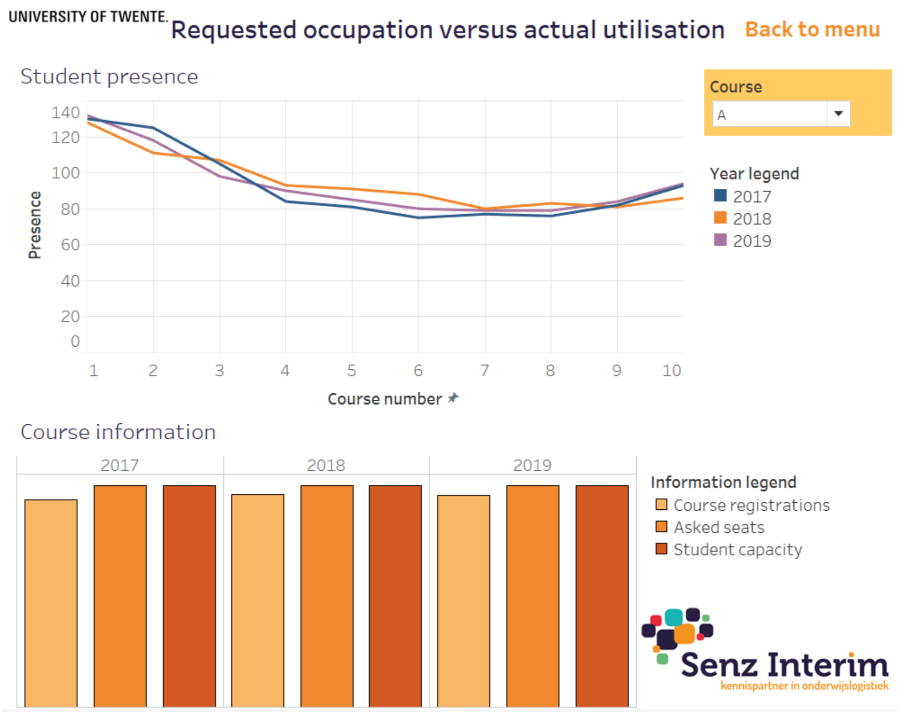

Figure 9; Dashboard requested occupation versus actual utilisation

5.2.5. Sheet 'Registrations academic year'

The last dashboard sheet consists of the KPIs within the category registrations academic year and can be seen in Figure 10. First, the total number of registrations is visualised by means of a line graph to see a trend over the past year. In addition, a trend line is implemented to foresee the trend and possible growth of registrations. Besides, the number of dropouts of the past couple of years is visualised with the use of a line graph as well as the number of first year students. All of the KPIs visualised can be filtered among different studies. Finally, the expectations of next year (2021) can be seen at the bottom of the dashboard. These expectations consist of the number of registrations, dropouts and first year students of next year. The numbers get affected by a change in the what-if scenario within this dashboard that can show the expectations of next year if the percentage of registrations increases or decreases from 2020.

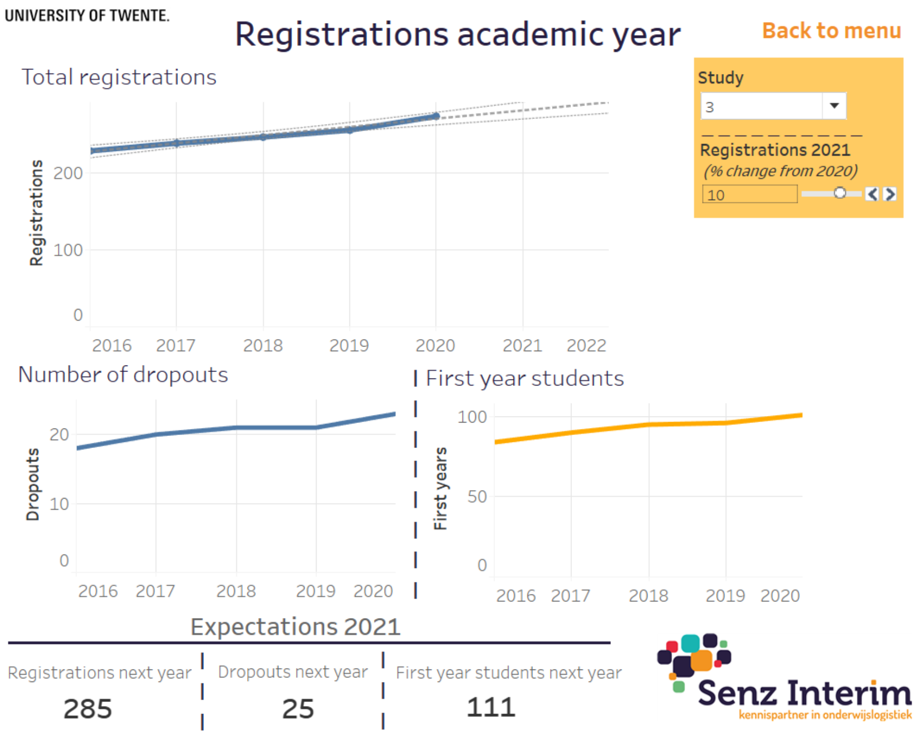

Figure 10; Dashboard registrations academic year

6. Conclusion, recommendations and limitations

The purpose of this research project was to solve the chosen core problem: *'At Senz Interim, there are currently no transparent and visual methods to gain insight in the consequences of changes in the planning process consisting of visualising the feasibility between different variables (e.g. students, teachers and capacity)'*. Solving this core problem would solve all related problems from the problem cluster as well. Finally solving the action problem that fewer problems related to educational planning will be found during a late stage of scheduling.

The research first was done to find KPIs related to educational planning that could visualise the current performance of a planning as well as the consequences of decisions. Additionally, dashboard guidelines, interactions and visualisations were researched to be able to provide user-friendly and effective dashboard design. Next, an analysis of the most suitable BI tool for this research and the wishes of Senz Interim has been conducted to be able to effectively make the visualisations.

This chapter provides a conclusion to what extent our provided solution, the implemented dashboards, solved the chosen core problem and its corresponding problems found within the problem cluster in Section 6.1. Afterwards, recommendations will be given in Section 6.2., based on the results of this research. At last, the limitations of this research will be discussed in Section 6.3.

6.1. Conclusion

The core problem would be solved if a method was realised which gave one visual and transparent insights into consequences of an event or decision within the domain of educational planning. The dashboards developed during this research are, first, able to show insights with regard to the current performance of a planning of a single institution. Besides, one is able to simulate events or decisions for this institution by means of what-if scenarios that a user is able to interact with. The what-if scenarios, consisting of a change in online lessons, room capacity and student registrations can impact various KPIs that show the feasibility between different variables and thus can show the consequences of a simulated event or decision. With this, one can conclude that the chosen core problem of this research has been solved.

Moreover, there can be proactively or predictively reacted to changes within the number of online lessons, room capacities and student registrations of an institution with the use of the dashboards. The effect or impact of various (future) scenarios on an educational planning can be made visible and transparent. This implies that Senz Interim is now able to react proactive or predictive to several possible changes regarding the visualised institution, by foreseeing the impact or consequences and responding in advance.

The developed BI tool during this research is able to provide useful insights for the corresponding institution where decisions can be based on in an early stage of educational planning. The educational planners are able to see the most crowded course hours and classrooms as well as the average lessons per day for a study for example, from which decisions can be based on. Because of this, problems related to the schedules of the used institution will be reduced.

At last, fewer problems are likely to occur during a late stage of scheduling of the used institution as a result of the previously solved problems. In order words, the developed BI tool will minimize the problems with scheduling, as the performance indicators are able to visualise possible perplexities of the current planning and when various scenarios are applied.

6.2. Recommendations

This section outlines recommendations regarding the advancement of developed BI tool within Senz Interim as well as other aspects that were pointed out during this research.

The developed BI tool of this research helps with the development of BI within Senz Interim. The KPIs established give a clear indication to what is possible to visualise with regard to educational planning. It is recommended that more dashboards will be created for multiple educational institutions that are willing to cooperate within the BI development. Ultimately, the development of a standard product with a selection of KPIs founded within this research that are applicable for multiple academies is recommended. A development of a DWH will be the most suitable option in the long term to be able to extract, transform and load all different types of data used by various packages of institutions in a generic way. Additionally, we recommend that the DWH is to be coupled to Tableau. This is because Tableau is found to be the most suitable BI tool that is able to visualise the KPIs effectively.

Next to the development of a standard BI product for the clients of Senz Interim, it is recommended that the dashboards will be maintained and expanded in the future. This implies that the data that acts as input for the BI tool, first, should be updated periodically in order to keep the visualizations up-to-date. Furthermore, it is recommended that the KPI selection as well as the what-if scenarios are further expanded on and researched. Meaning that scenarios, such as the possibility to change the room capacity per classroom type as well as the possibilities to remove a certain classroom or building can be implemented. This will result in more proactive or predictive reactions to imaginable issues related to educational planning and ultimately will lead to more customer satisfaction.

The last recommendation is to implement the option for users to be able to compile their own dashboards. Instead of creating pre-established dashboards, it is recommended that dashboards users are able to choose the visualizations or insights that they want to see in the future. This would decrease perplexity among users and will increase the user-friendliness of the tool.

6.3. Limitations

Within this section, the limitations that could have been an influence to the outcome of this research are discussed.

First of all, not all data of the clients of Senz Interim was available for the development of the BI tool during this research. Data regarding teachers, for instance, was completely left out of the tool as this data was not given available for conducting this research. Furthermore, the lack of some data resulted in several dummy data to act as input for the tool. This made the visualisation of several KPIs to be not fully realistic.

Secondly, the what-if scenario within the BI tool concerning a change in the number of online lessons, randomly put location lessons to online lessons. This might not be the case in practice, since there can be preferences to lessons that are most convenient to be held online. Whereas, as of right now some lessons that are preferred to be held on location can be put online which is not the optimal situation.

Context awareness can be seen as another limitation of this research. This is because the intentions of the institution, from which a large part of the existing data was used for the development of the BI tool, were not given. In other words, the norms and values concerning the KPIs were unknown. For example, it is unknown what number of students there are simultaneously present at the institution are considered 'too many' and should be coloured red or yellow. The result of the lack of context awareness on the outcome of this research was it was not possible to determine when issues would occur and when notifications, alerts or colouring should be applied within the KPIs.

Finally, the time in which the bachelor thesis has been executed was ten weeks. This limited the possibility for extensive research. In addition, the research is conducted during the COVID-19 pandemic. As a result, online contact and communication was not always convenient, as sudden interactions and feedback from the colleagues of the company were limited.

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Appendices

Appendix A: Problem cluster explanation

Currently, Senz Interim has no methods available to gain insight in the consequences of changes within the planning process. Many institutions do not have the skills, knowledge or time to gain insight on the consequences of a changed factor on their planning and capacity. For example, after the first measures were implemented in the Netherlands to diminish the spread of COVID-19, student numbers allowed to be in the same class were limited as a result. It was difficult to oversee the actual impact of these kind of changes caused by the virus and, as a consequence, new regulations defined at the level of government as well as the university. Generally speaking, it is important to provide educational institutions with insight into the consequences or impact of their specific situation at the beginning of the process, so that they can make decisions based on data and predictions.

Additionally, Senz Interim does not have access to all data of institutions. In order to give proper advice to schedulers or the educational logistics in general, delivering data is required from clients to Senz Interim. Mainly because of privacy purposes, clients do not deliver all data of their institution to Senz Interim.

The result of inaccessibility to all data of institutions as well as absence of methods available to gain insight on the impact of changes is that in an early stage of the planning process, decisions are often made with wrong insights. There needs to be sufficient data in order to make appropriate decisions or predictions regarding a planning or schedule of an institution.

Decisions that are being made with wrong insights in the planning process can lead to a planning of staff, e.g. teachers, that is not feasible. This could mean that a teacher for example possibly has to give more hours of lessons than noted in the contract. Moreover, there can be problems with the capacity of several classrooms as a result. For instance, a classroom can be too small for a certain class, which is especially the case with the current situation with the pandemics. As a result, this type of unexpected changes and their impacts will result in a non-optimal planning for institutions.

Furthermore, there is a lack of knowledge by Interim schedulers in the early stages of the planning process. This means that the actual schedulers, which act at a later stage of the planning process, lack knowledge to have input in the early stages of the process.

Another problem that currently occurs at Senz Interim is that one does not know what to do with existing data. There is plenty of data available that can be used for predictions to make a planning more optimal for example. However, nothing is currently done with this data.

As a result, the potential of Senz Interim to react proactive or predictive to changes is limited. Once sudden changes happen within a planning of an institution, Senz Interim is not flexible to be able to react quickly.

Because of the lack of knowledge by schedulers in early stages of the planning process, decisions in these early stages are often made with wrong insights and Senz Interim is not able to react proactive or predictive, one often finds too many problems late within the planning process. Schedulers are often closely related to an institution and can have knowledge about certain factors that can influence a planning. However, as schedulers often have no input in early stages because of the lack of knowledge (not skilled for making predictions and optimising schedules), problems are found within the planning at a late stage. This means that last-minute adaptations can occur. Sometimes, last-minute adaptations occur because of changes that are not controllable (late enrolments or absence of teachers). However, the last-minute changes are often caused because of several controllable mistakes (wrong estimates or calculations). All last-minute bother Senz Interim as adaptations can have a drastic impact on students and teachers, as their schedules are being changed at the last moment. Moreover, for these last-minute adaptations, sometimes a whole planning needs to be revamped because of several mistakes. This often results in a high workload and stress for the educational planners as a lot of work needs to be done within a short period of time in order to let an institution function properly.

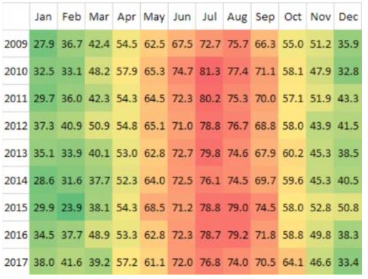
Appendix B: Dashboard principles

Table B.1; Dashboard principles with descriptions

Principle/guideline	Description
1) Navigation	The implementation of logical navigation patterns and menus, so users can explore data with confidence and quickly trance their progress throughout the dashboard hierarchy. There, should be a clear path visible that guides a user toward different information that is represented on a dashboard.
2) Style	The overall look and feel of a dashboard should be representative of a company and should be applied consistently. There should be no ambiguity in the look and feel of the dashboard. Meaning that, preferably, all pages and themes should remain the same throughout different areas of the dashboard.
3) Linking items	Linking or grouping the KPIs of a dashboard is essential in effective visualization, representation of the missing information, and interpretation support.
4) Data types	Both real-time and historic data should be arranged logically and grouped thematically on a dashboard.
5) Communication	The contents should be clear and understandable for the user of a dashboard. One should use effective language and appropriate visualisations (e.g. graphs or colouring) on a dashboard for proper communication.
6) Possibilities and conjectures	Dashboards should enable organizations to analyse different scenarios and future conjectures for measuring, benchmarking, and improving organizational settings.

Appendix C: Graph types

Table C.1; Graph types



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2009	27.9	36.7	42.4	54.5	62.5	67.5	72.7	75.7	66.3	55.0	51.2	35.9
2010	32.5	33.1	48.2	57.9	65.3	74.7	81.3	77.4	71.1	58.1	47.9	32.8
2011	29.7	36.0	42.3	54.3	64.5	72.3	80.2	75.3	70.0	57.1	51.9	43.3
2012	37.3	40.9	50.9	54.8	65.1	71.0	78.8	76.7	68.8	58.0	43.9	41.5
2013	35.1	33.9	40.1	53.0	62.8	72.7	79.8	74.6	67.9	60.2	45.3	38.5
2014	28.6	31.6	37.7	52.3	64.0	72.5	76.1	74.5	69.7	59.6	45.3	40.5
2015	29.9	23.9	38.1	54.3	68.5	71.2	78.8	79.0	74.5	58.0	52.8	50.8
2016	34.5	37.7	48.9	53.3	62.8	72.3	78.7	79.2	71.8	58.8	49.8	38.3
2017	38.0	41.6	39.2	57.2	61.1	72.0	76.8	74.0	70.5	64.1	46.6	33.4

Figure C.1; Heat map

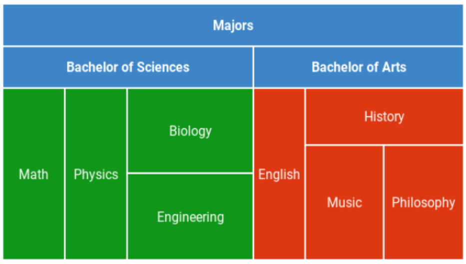


Figure C.2; Tree map

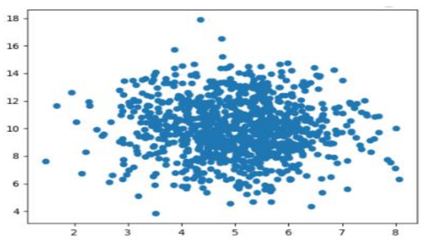


Figure C.3; Scatter plot

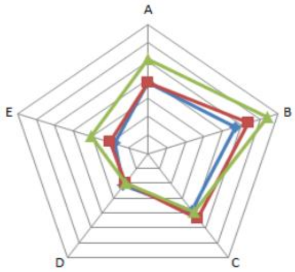


Figure C.4; Radar chart

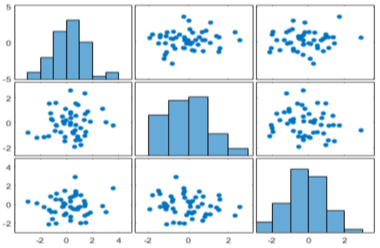


Figure C.5; Scatter plot matrix

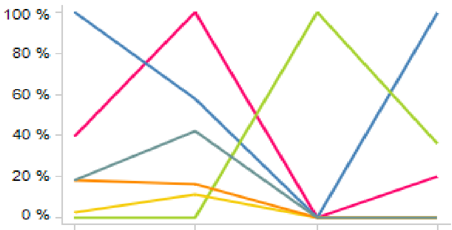


Figure C.6; Parallel coordinates plot

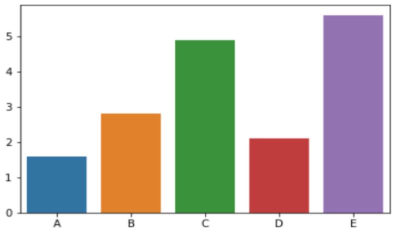


Figure C.7; Bar graph

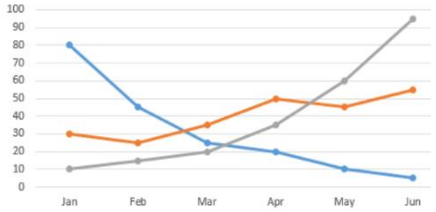


Figure C.8; Line graph

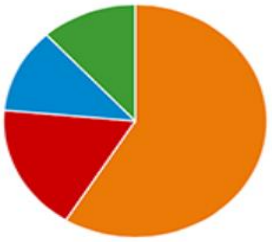


Figure C.9; Pie chart

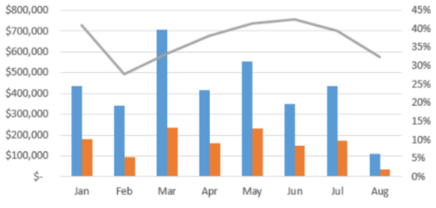


Figure C.10; Combined chart

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Appendix D: AHP

This Appendix describes all the steps that were taken in the AHP to find the most suitable BI tool for my research. First of all, the preference scale for pairwise comparisons of criteria and alternatives is essential for proper execution of the AHP. This preference scale translates verbal statements into numerical values according to a 1-9 scale, as can be seen in Table D.1.

Table D.1; Preference scale

Preference level	**Numeric value**
Equally preferred	1
Equally to moderately preferred	2
Moderately preferred	3
Moderately to strongly preferred	4
Strongly preferred	5
Strongly to very strongly preferred	6
Very strongly preferred	7
Very strongly to extremely preferred	8
Extremely preferred	9

Ranking criteria

Within this step of the AHP, the criteria for a BI tool are compared and ranked. This is an important part of the AHP, as various criteria are often valued differently. The pairwise comparisons of all the criteria can be seen in Table D.2, based on the rounded average values of three consultants. Within these comparisons, the criteria on the x-axis are compared to the y-axis of the matrix in Table D.2. A value of 5, for instance, implies that the corresponding criteria on the x-axis sis strongly preferred over the criteria mentioned on the y-axis. A preference vector for the criteria is established from the comparisons, which is shown in Table D.3, where a certain weight is assigned to each criteria. This preference vector is calculated by, first, dividing each pairwise comparison with the column sum to create a so-called normalized matrix. The row averages from this matrix together form the preference vector.

Table D.2; Pairwise comparisons for criteria

	Visualisation	Cost	User-friendliness	Mobile app
Visualisation	1	6	2	7
Cost	1/6	1	1/3	3
User-frienliness	1/2	3	1	5
Mobile app	1/7	1/3	1/5	1
Sum	1 17/21	10 1/3	3 8/15	16

Table D.3; Preference vector for criteria

Criteria	**Weight**
Visualisation	0,534204
Cost	0,11768
User-frienliness	0,290539
Mobile app	0,057577

Pairwise comparisons

The pairwise comparisons of all of the decision alternatives for each criteria can be seen in Tables D.4-D.7. The values of the comparisons are based on the findings stated within Section 4.3 of the report. A preference matrix is made with the use of these pairwise comparisons, which is visualised in Table D.8. This preference matrix is established by, first, dividing the value of each comparison by the column sum to create a normalized matrix for each criteria. The row averages from the normalized matrices eventually create the values that can be seen within the preference matrix (Taherdoost, 2017).

Table D.4; Pairwise comparisons visualisation

Visualisation					
	Power BI	Tableau	Qlik	SSRS	Excel
Power BI	1	1/2	1/2	2	5
Tableau	2	1	1	3	6
Qlik	2	1	1	3	6
SSRS	1/2	1/3	1/3	1	3
Excel	1/5	1/6	1/6	1/3	1

Table D.5; Pairwise comparisons cost

Cost					
	Power BI	Tableau	Qlik	SSRS	Excel
Power BI	1	3	2	2	1/5
Tableau	1/3	1	1/2	1/2	1/6
Qlik	1/2	2	1	1	1/6
SSRS	1/2	2	1	1	1/6
Excel	5	6	6	6	1

Table D.6; Pairwise comparisons user-friendliness

User-friendliness					
	Power BI	Tableau	Qlik	SSRS	Excel
Power BI	1	1/3	1/3	2	4
Tableau	3	1	2	4	5
Qlik	3	1/2	1	1	5
SSRS	1/2	1/4	1/4	1	2
Excel	1/4	1/5	1/5	1/2	1

Table D.7; Pairwise comparisons mobile app

Mobile app					
	Power BI	Tableau	Qlik	SSRS	Excel
Power BI	1	1	1	1	5
Tableau	1	1	1	1	5
Qlik	1	1	1	1	5
SSRS	1	1	1	1	5
Excel	1/5	1/5	1/5	1/5	1

Table D.8; Preference matrix

	Criterion			
	Visualisations	Cost	User-frienliness	Mobile app
Power BI	0,1922	0,1698	0,1545	0,2381
Tableau	0,3249	0,0620	0,3991	0,2381
Qlik	0,3249	0,0999	0,3025	0,2381
SSRS	0,1120	0,0999	0,0889	0,2381
Excel	0,0459	0,5683	0,0550	0,0476

Overall ranking

The overall ranking is generated by multiplying the values of each alternative that are stated within the preference matrix with the criteria weights and can be seen in Table D.9. From this, one can conclude that Tableau is the most suitable BI tool for this research.

Table D.9; Overall ranking of alternatives

BI tool	Score
Power BI	0,18127
Tableau	0,31055
Qlik	0,28693
SSRS	0,11113
Excel	0,11012

Consistency

To finalise the AHP, a check for the consistency and validity of the conducted pairwise comparisons needs to be done. The consistency of the pairwise comparisons of both the criteria and alternatives is checked and can be seen in Table D.10. To check the consistency, one needs to multiply the pairwise comparison matrices with the row averages of the normalized matrices (preference vectors) (Taherdoost, 2017). The average of the multiplications of the two matrices is divided by the number of items that are compared (n) to create the λmax.

The consistency index (CI) and consistency ratio (CR) are calculated according to the following formulas:

$$CI = (\lambda\text{max} - \text{n}) / (\text{n} - 1)$$

$$CR = CI/RI$$

Where λmax is calculated previously, n is the number of items that are compared and RI are the random index values for n items that are being compared (see Table D.11). The degree of consistency is satisfactory if CR < 0,10 (Taherdoost, 2017).

Table D.10; Consistency for criteria and alternatives

	λmax	CI	CR
Criterion	4,0881	0,0294	0,0326
Visualisation	5,0423	0,0106	0,0094
Cost	5,1013	0,0253	0,0226
User-friendliness	5,1527	0,0382	0,0341
Mobile app	5,0000	0	0

Table D.11; Random index values for n compared items

n	2	3	4	5	6	7	8	9	10
RI	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,51

Appendix E: Manual

This Appendix provides a manual that describes all dashboard sheets, visualisations and drill down options from the results of this research in detail. This manual elaborates more on various aspects of the developed dashboards in comparison with Section 5.2.

Menu

The first sheet of the BI tool results consists of a menu from which a user can navigate to various dashboard sheets that each visualises the KPIs of a certain category mentioned in Section 2.5. (see Figure E.1). A user can interact (click) on ‘Occupancy online/ on location’ , ‘Occupation per location’, ‘Student satisfaction’, ‘Requested occupation versus actual utilisation’ or ‘Registrations academic year’ to navigate to the corresponding dashboards. Moreover, on the menu page named ‘Thesis visualisations’, the logos of Senz Interim (as research company) and the University of Twente (as the research academy) are visualised.

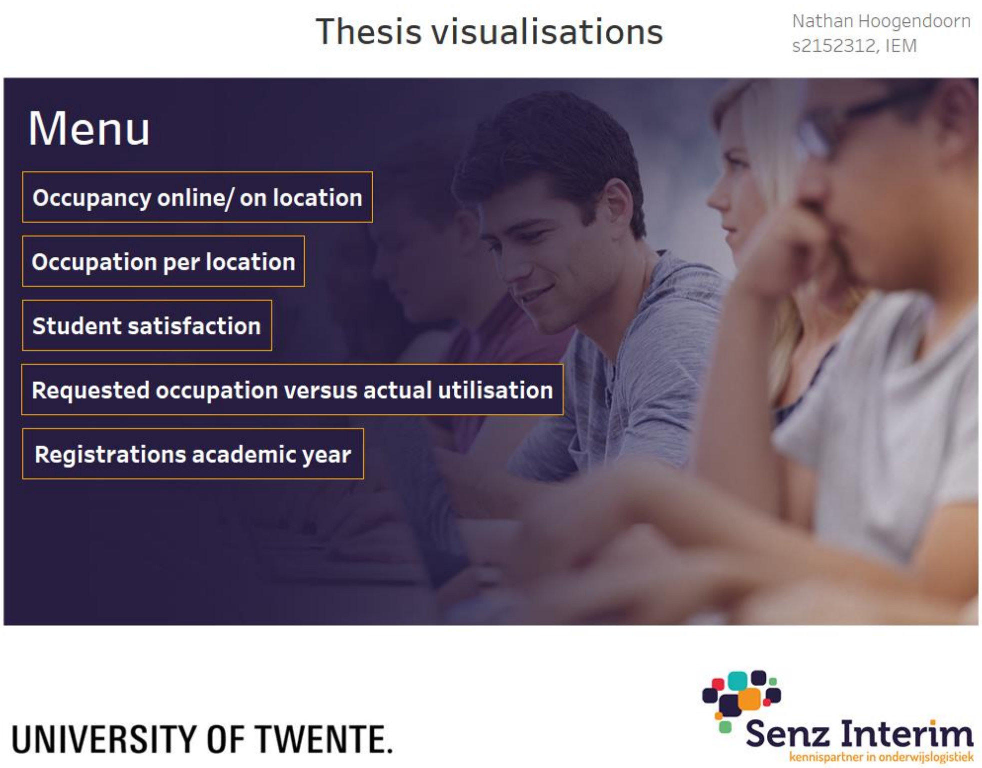


Figure E.1; Menu BI tool

Occupancy online/ on location

Once a user clicks on the first navigation box ‘Occupancy online/ on location’, the user will navigate to the dashboard sheet of this category seen in Figure E.2. This dashboards sheet visualises the KPIs within the category occupancy online/ on location. First of all, the percentage of online lessons of the entire institution is stated. Moreover, the total students that are present during various block hours is visualised by means of a tree map. A block hour consists of two course hours, meaning that the third (most crowded) block hour consists of course hours 5 and 6. Filters on academic year and period (quartile) can be applied on the KPIs on this dashboard sheet and can be seen in an orange box at the top right of the sheet. A user can filter between the academic years ‘2019-2020’ and ‘2020-2021’ by interacting with the drop down menu of the ‘Academic year’ filter, as can be seen in Figure E.3. Besides, a user can choose between four different periods (quartiles), namely ‘P1’, ‘P2’, ‘P3’ and ‘P4’ once interacting with the dropdown menu of the ‘Period’ filter (Figure E.4). A user can always return back to the menu once clicking with the ‘Back to menu’ button on the top right of the dashboard.

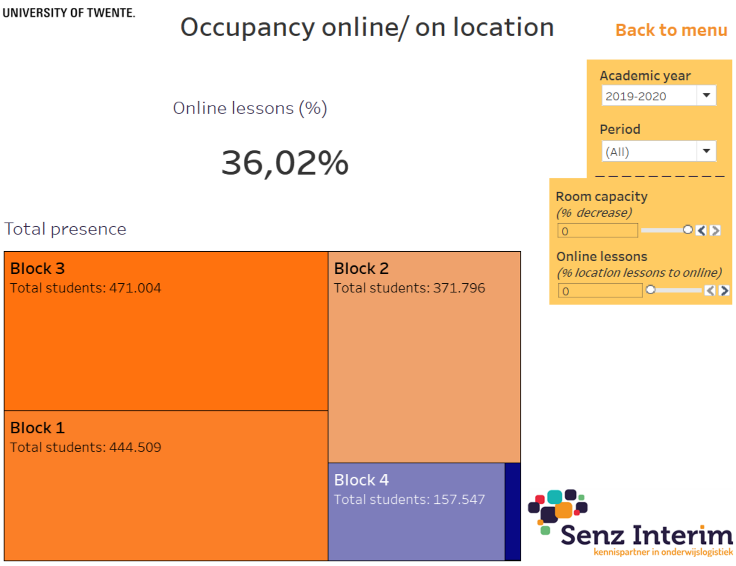


Figure E.2; Sheet Occupancy online/ on location

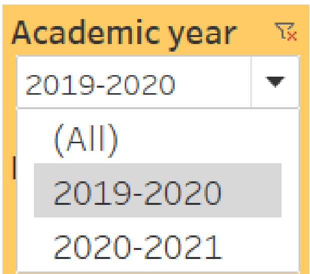


Figure E.3; Academic year filter

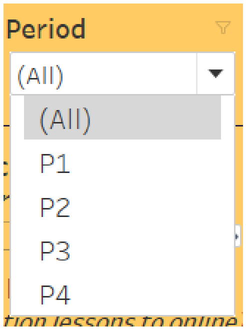


Figure E.4; Period filter

In addition, two what-if scenarios can affect the visualisations on this dashboard and can be seen right under the filters. First of all, the room capacity can decrease according to a percentage. The what-if scenario of the room capacity is a slider that a user can interact with to decrease the room capacity of all classrooms with a percentage. This percentage can range from 0 till 75% decrease with steps of 1%. Besides, the number of online lessons can increase in percentage of offline (on location) lessons that change to online lessons. This what-if scenario also consists of a slider that a user can interact with to change the percentage of location lessons that will be (randomly) set to online. The percentage of this slider ranges from 0 till 100% with steps of 5%. Changes within both scenarios affect both the percentage of online lessons and total student presence on the dashboard. An example of this can be seen in Figure E.5.

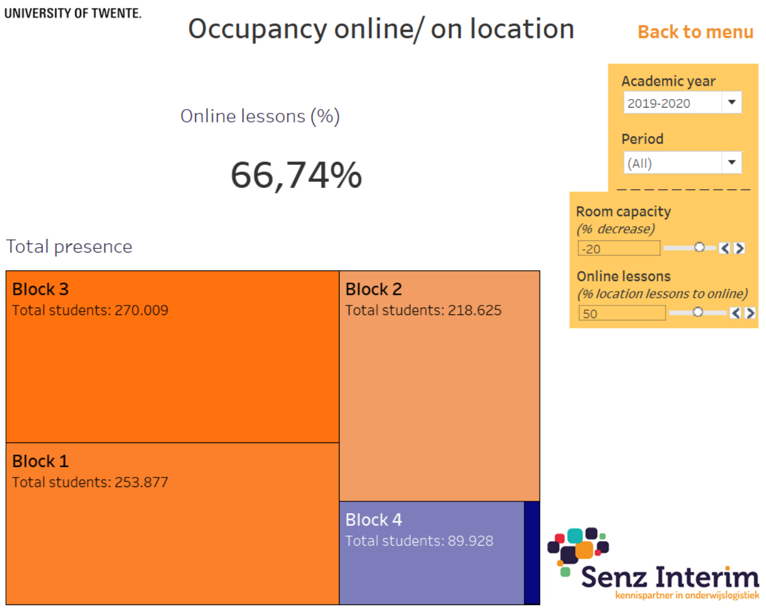


Figure E.5; Occupancy online/ on location with what-if scenario change

A drill down option is available for the total student presence KPI. First, a user can see a visualisation in the tooltip of the total presence tree map once hovering over the KPI with a mouse as seen in Figure E.6. At the bottom of the tooltip the words '*Click to drill down*' are stated, meaning that a user can click on a specific block hour on the tree map of the total student presence to drill down into more detail.

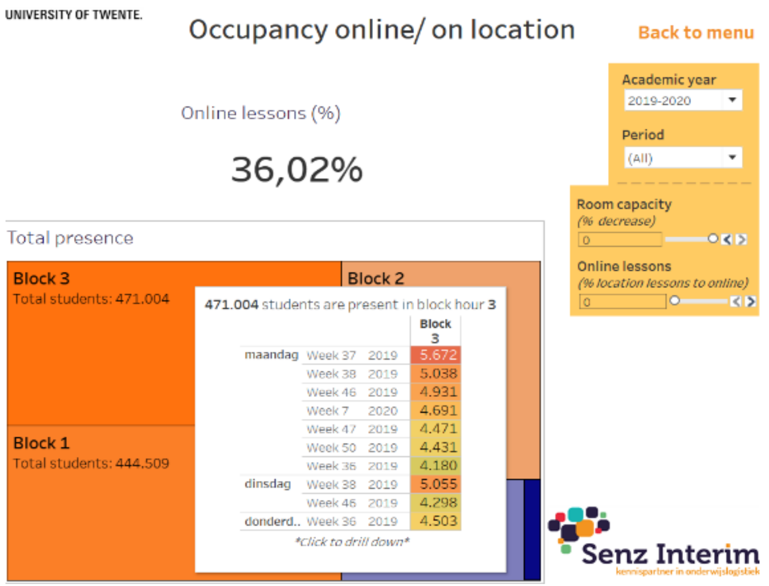


Figure E.6; Tooltip total presence

Once drilling down, a user is navigated to another dashboard sheet that shows the top student presence of the block hour that was clicked on (see Figure E.7) in a table/ heat map. This dashboard sheet consists of the top N most crowded days (with week number and year) during the selected block hour. A user can apply filters on academic year and period to see the most crowded days at a block hour during a specific time period, which are on the top right of the dashboard. Just underneath the filters is a colour legend which shows when a colour is applied. The colour red indicates that there are too many students present, whereas the colour yellow shows that the institution has to be cautious with the number of students present during the block hour. The colour green indicates that everything is fine and that there are not too many students present. The values of the colours can be set to the standards of an institution in the future if these are known.

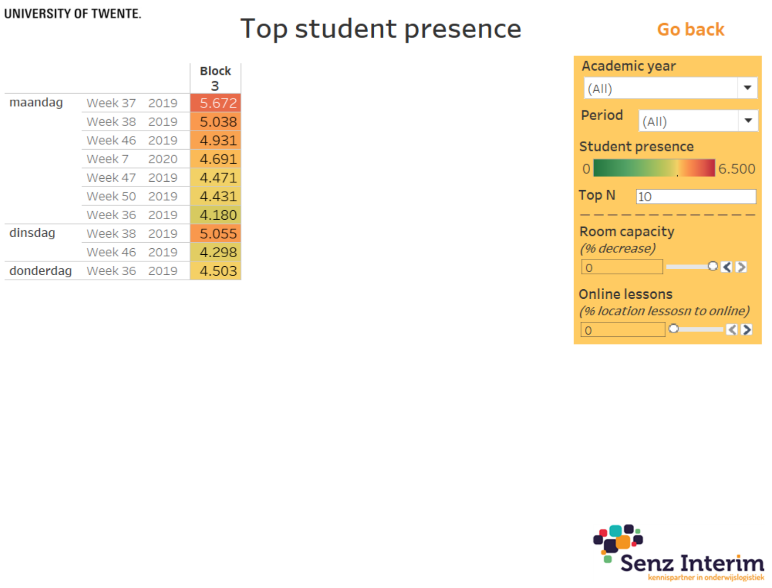


Figure E.7; Top student presence sheet

The ‘top N’ filter is situated underneath the colour legend and is a filter which a user can type in a number between 0 and 30 to show the top N most crowded moments during the selected block hour. Moreover, the what-if scenarios of room capacity changes and online lessons changes impact the student presence. Figure E.8 gives an example of the top student presence when the N is changed to 15 and the room capacity decreases with 50 percent.

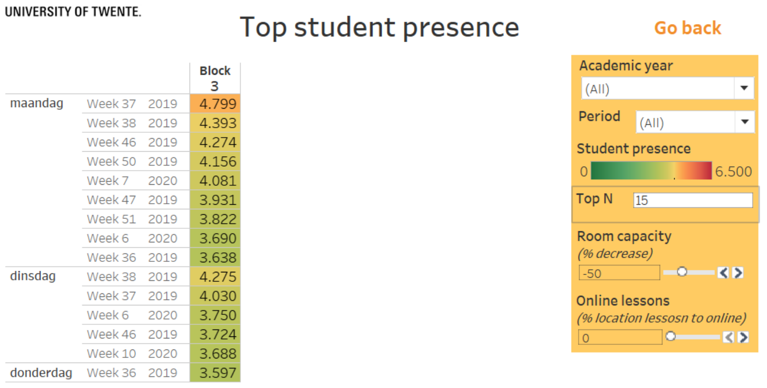


Figure E.8; Top student presence top N and what-if scenario change example

A user can easily navigate back to the ‘Occupancy online/ on location’ dashboard sheet once clicking on the ‘Go back’ button on the top right of the dashboard (both academic year and period filters on the Top student presence dashboard sheet should be ‘(All)’ in order to return properly).

Occupation per location

Once a user makes its way to the dashboard sheet named 'Occupation per location' from the menu, it will show the KPIs mentioned within the category occupation per location with two additional indicators (see Figure E.9). The top left graph on the dashboard is an additional KPI which shows the number of scheduled lessons per course hour (room occupancies) for the buildings with the corresponding 'Room type' filter in a line graph. The room occupancy KPI is visualised in a tree map in the bottom left of the sheet and shows the number and percentage of scheduled lessons per classroom of the corresponding 'Room type' filter value. Furthermore, the room suitability is visualised in a pie chart on the dashboard and shows the number and distribution of classroom types that are used per study or time period once a user hovers its mouse of the visualisation (see Figure E.10). A distinction was made between six different room types, namely Exam, HC (lecture room), Lab, Online, WC (tutorial room) and WC Digi (tutorial room including digital devices) which can be seen in the room type colour legend. Finally, the bottom right bar chart is another additional KPI that shows the average room occupancies for all of the different classroom types.

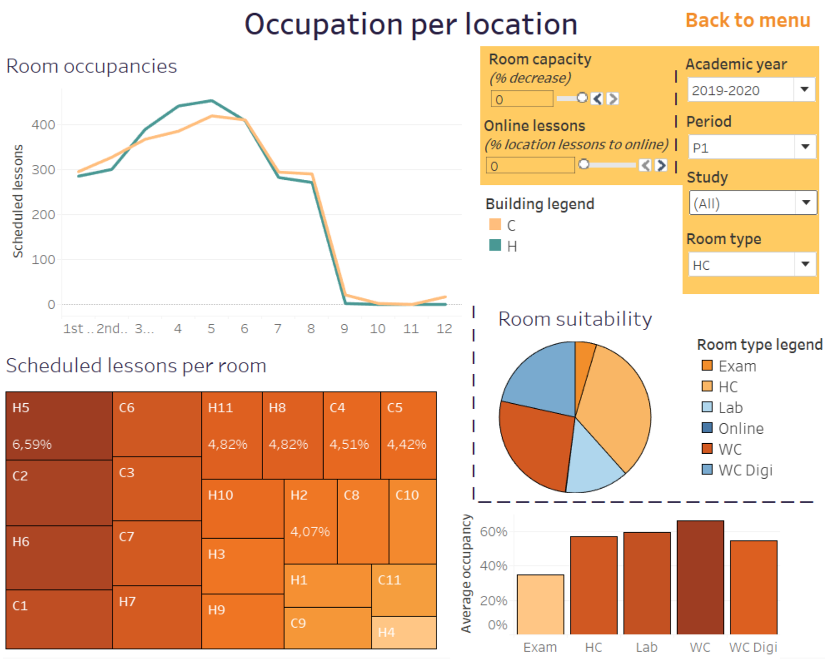


Figure E.9; Occupation per location dashboard sheet

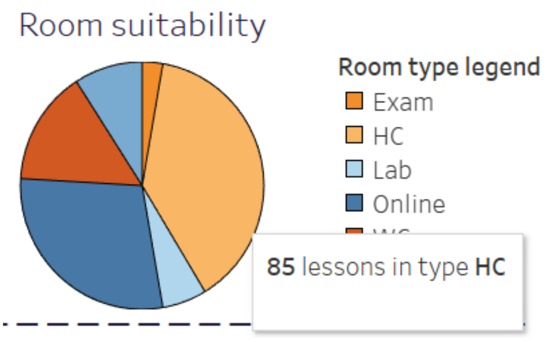


Figure E.10; Room suitabiltiy KPI

A user is able to filter on different academic years and periods that affect the whole dashboard, which can be seen in Figures E.3 and E.4 respectively. Moreover, one is able to filter on different studies that impact the room suitability KPI. There are a total of 44 studies that a user is able to filter upon using a dropdown menu, as can be seen in Figure E.11. Besides, a 'Room type' filter can be applied that impacts the line graph and tree map on the left hand side of the sheet, as the insights for buildings and classrooms of different room types can be seen. This filter consists of the various room types mentioned previously and can be seen in Figure E.12.

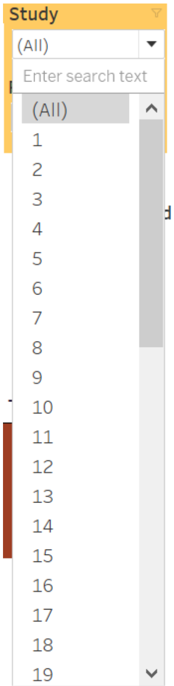


Figure E.11; Study type filter

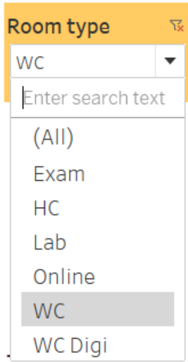


Figure E.12; Room type filter

Finally, the two what-if scenarios that were on the previous dashboard sheet are incorporated in this dashboard as well. Changing these scenarios can show the impact on the KPIs that are visualised. Changing the room capacity affects the average room occupancies and changing the online lessons affects the number of scheduled lessons and the room occupancies. An example of the impact of a change in room type and changes within the what-if scenarios can be seen in Figure E.13.

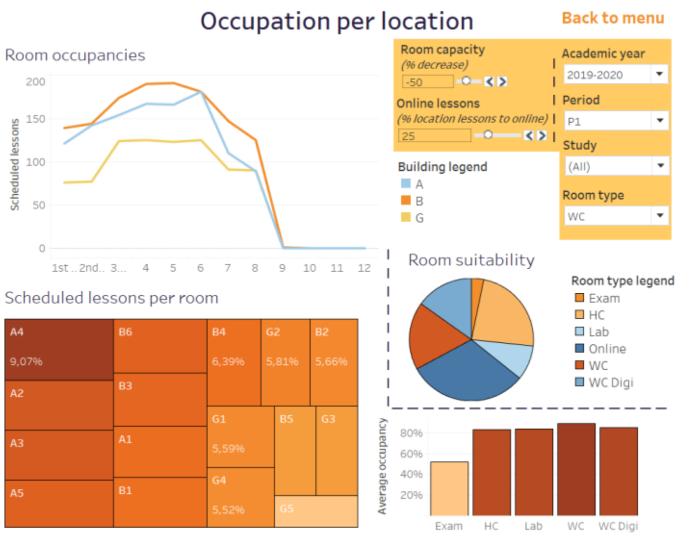


Figure E.13; Room type and what-if scenario changes example

There is a drill down option available on the average occupancy bar chart on the bottom right of the dashboard. Once a user hovers its mouse over a certain room type of this graph, the sentence '*Click to drill down*' appears (see Figure E.14).

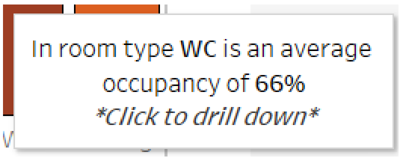


Figure E.14; Tooltip average occupancy

When drilling down, a user will be navigated to another dashboard sheet consisting of details regarding the room occupancies, see Figure E.15. Within this sheet, all the room names of the selected room type are stated on the y-axis. The bar chart seen in the dashboard sheet visualises the total room capacity of each classroom, the maximum students that are actually scheduled within a classroom and the average number of students scheduled within each classroom. This bar chart can be filtered on academic year and period in the orange box on the top right of the dashboard.

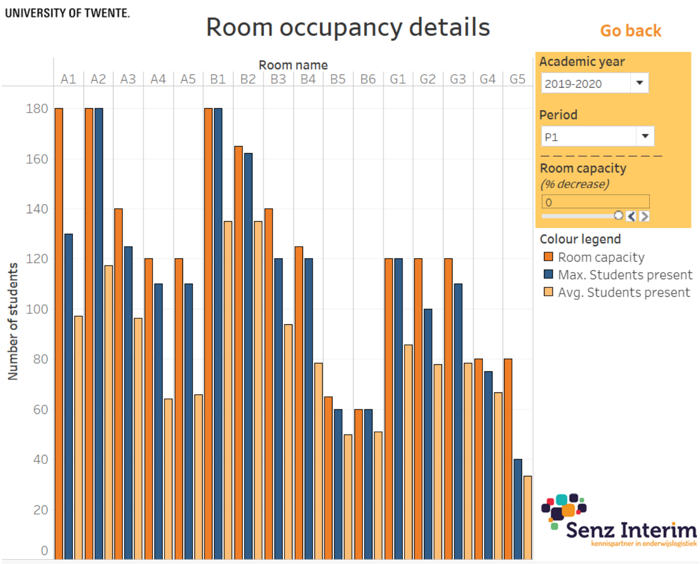


Figure E.15; Room occupancy details drill down

In addition, one is able to decrease the room capacity of every classroom with the what-if scenario slider underneath the filters. Once this slider changes, the total room capacity decreases and the maximum students scheduled will be equal to the total capacity once this exceeds the changed capacity. An example of a decrease in the room capacity can be seen in Figure E.16.

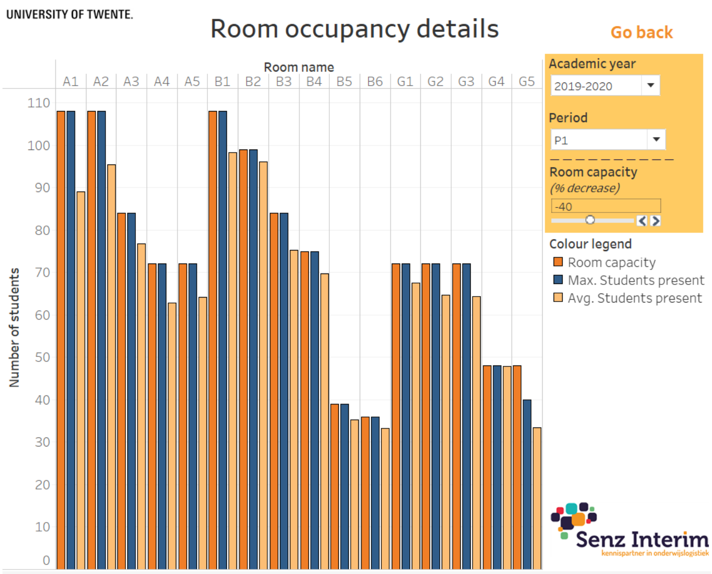


Figure E.16; Room capacity change example

Yet another drill down option is available on the room occupancy details dashboard sheet, as '*Click to drill down*' occurs once hovering a mouse over the bar chart (see Figure E.17)

Once clicking on the bar chart, a user navigates to another dashboard sheet where one is able to see the lessons within the selected classroom that are affected by a capacity change in a chosen time filter. The sheet shows the specific date, study type and selected classroom that is affected (will have too many students present in the classroom with the capacity change), see Figure E.18. This dashboard sheet will be blank if there are no lessons affected for the selected classroom by a room capacity change.

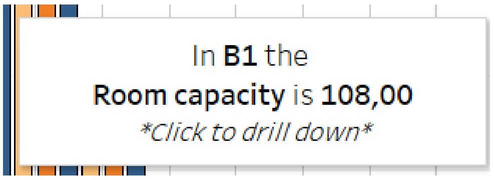
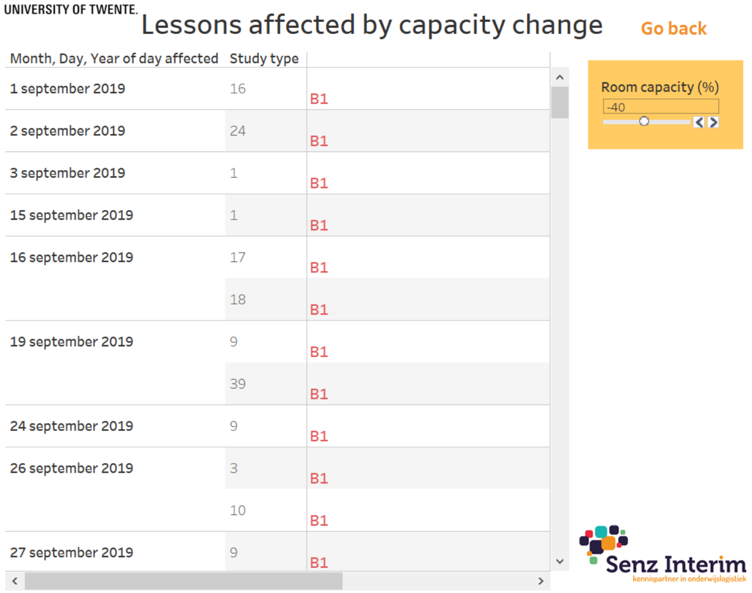


Figure E.17; Tooltip room occupancy details



Month, Day, Year of day affected	Study type	
1 september 2019	16	B1
2 september 2019	24	B1
3 september 2019	1	B1
15 september 2019	1	B1
16 september 2019	17	B1
	18	B1
19 september 2019	9	B1
	39	B1
24 september 2019	9	B1
26 september 2019	3	B1
	10	B1
27 september 2019	9	B1

Figure E.18; Lessons affected by capacity change drilldown

Users are able to navigate to the previous drill down or dashboard sheet by clicking on the 'Go back' button on the top right of the dashboard sheet.

There is another drill down possibility on the 'Occupancy online/ on location' sheet, but now for the room occupancies visualisation at the top left of the dashboard in Figure E.9. Once a user hovers its mouse over the line graph of a certain building, the words '*Click to drill down*' occur as can be seen in Figure E.19.

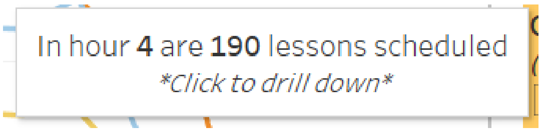
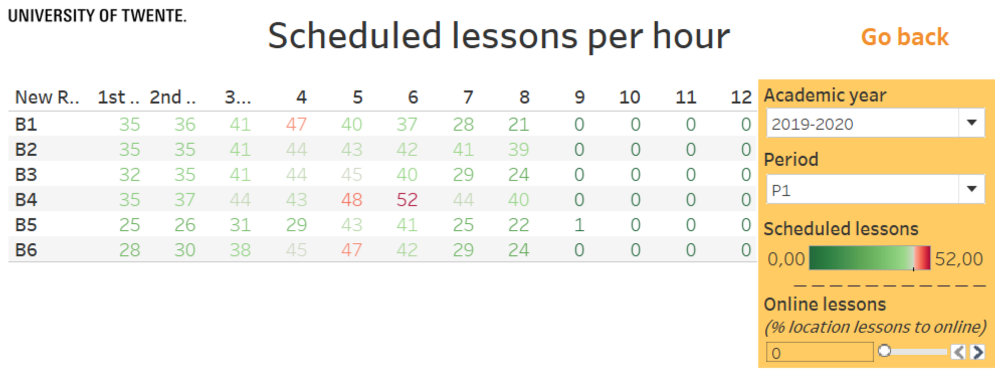


Figure E.19; Tooltip room occupancies

Once clicking on the line graph for the drill down, a user navigates to another dashboard sheet named 'Scheduled lessons per hour'. On this sheet, one is able to see the specific number of lessons that are scheduled per classroom of the selected building, see Figure E.20. This dashboard can be filtered per academic year and period on the top right of the sheet. Moreover, a colour legend is available which indicates when the number of scheduled lessons per room in an hour is high. A value around 50 lessons is indicated in yellow or red and indicates that this number is quite high. In addition, a user is able to change the what-if scenario regarding online lessons to see the impact on a change in this scenario to the scheduled lessons per hour.



New R..	1st ..	2nd ..	3...	4	5	6	7	8	9	10	11	12
B1	35	36	41	47	40	37	28	21	0	0	0	0
B2	35	35	41	44	43	42	41	39	0	0	0	0
B3	32	35	41	44	45	40	29	24	0	0	0	0
B4	35	37	44	43	48	52	44	40	0	0	0	0
B5	25	26	31	29	43	41	25	22	1	0	0	0
B6	28	30	38	45	47	42	29	24	0	0	0	0

Figure E.20; Scheduled lessons per hour drill down

Once a user hovers its mouse over a specific value of the scheduled hour per lesson, the text '*Click to drill down*' appears, as seen in Figure E.21. This means that another drill down possibility is available once clicking on a value on the scheduled lessons per hour sheet.

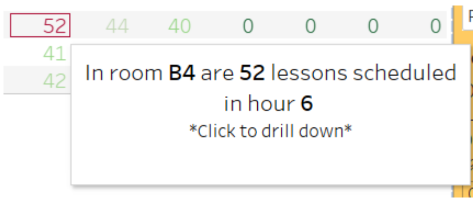
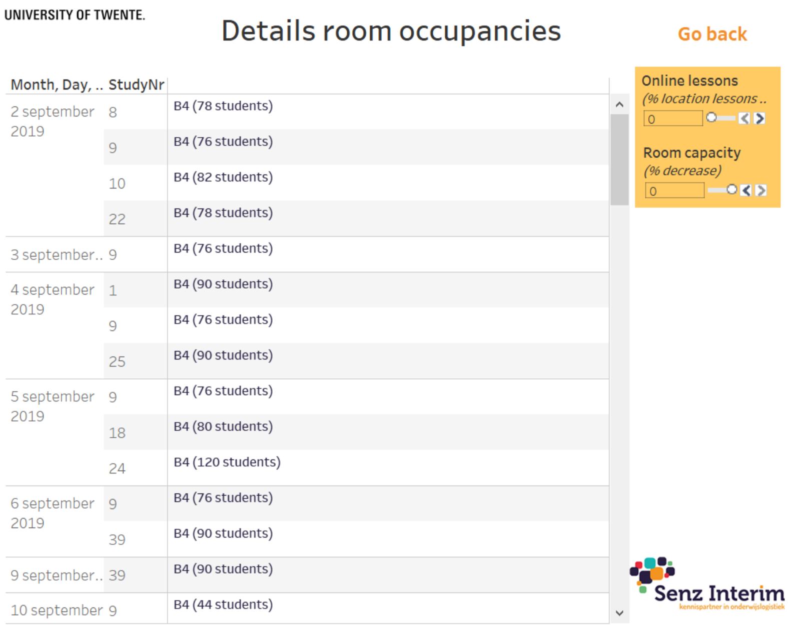


Figure E.21; Tooltip scheduled lessons per hour

Once clicking, a user navigates to another sheet that shows details about these scheduled lessons (see Figure E.22). The sheet shows details about all of the lessons, including dates of the selected time interval, study type and number of students that are scheduled in the selected room. A user is able to change the scenarios of online lessons and room capacity on this sheet to see the impact on the lessons during the selected hour.



Month, Day, ..	StudyNr	
2 september 2019	8	B4 (78 students)
	9	B4 (76 students)
	10	B4 (82 students)
	22	B4 (78 students)
3 september..	9	B4 (76 students)
4 september 2019	1	B4 (90 students)
	9	B4 (76 students)
	25	B4 (90 students)
5 september 2019	9	B4 (76 students)
	18	B4 (80 students)
	24	B4 (120 students)
6 september 2019	9	B4 (76 students)
	39	B4 (90 students)
9 september..	39	B4 (90 students)
10 september	9	B4 (44 students)

Figure E.22; Details room occupancies drilldown

Student satisfaction

If a user navigates from the menu to the student satisfaction sheet, one is able to see the KPIs regarding this category as seen in Figure E.23 This dashboard, first, shows numbers regarding the percentage of online lessons, the average lessons per day (curriculum compactness) and the lesson free days. Moreover, the maximum student load is visualised by means of a bar chart in the top left and shows the number of lessons after 17:30hrs per period. Finally, the number of experienced schedule changes is visualised with a pie chart. Various types of schedule changes can occur, namely a course class change, course delete, course hour change, new/extra lesson, teacher change and other. These types of changes are visualised in the pie chart and can be seen in the changes colour legend right next to the visualisation. The values within the pie chart can be made visible one a user hovers its mouse cursor over the pie chart, as shown in Figure E.24.

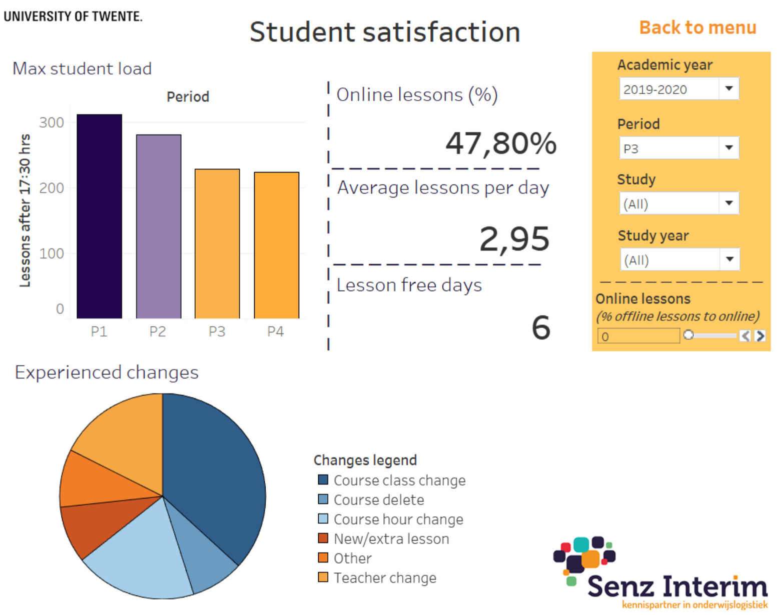


Figure E.23; Student satisfaction dashboard sheet

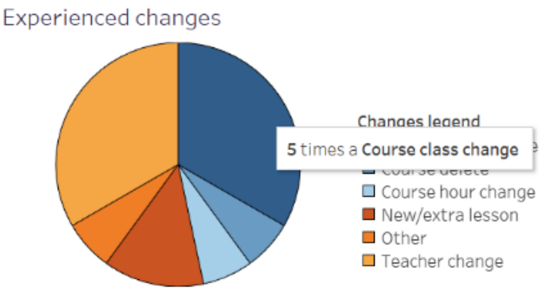


Figure E.24; Experienced changes pie chart

The filters can be found in the top right of this dashboard sheet. The filters 'Academic year', 'Period' and 'Study' are applicable to every KPI on this dashboard. In addition to these filters, the filter 'Study year' can also be used on the maximum student load, percentage of online lessons and the average lessons per day. This filter (Figure E.25) consists of the study years that occur and can have a value of 1, 2 or 3.

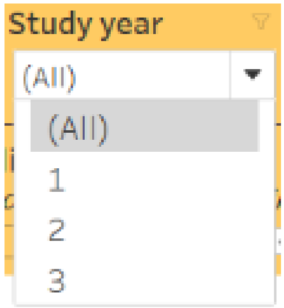


Figure E.25; Study year filter

Finally, the what-if scenario regarding online lessons can be used on this dashboard. The what-if scenario of an increase in the percentage of offline lessons put online is also implemented within this dashboard and solely impacts the percentage of online lessons. An example of change in the online lessons scenario as well as the application of the 'Study' filter can be seen in Figure E.26.

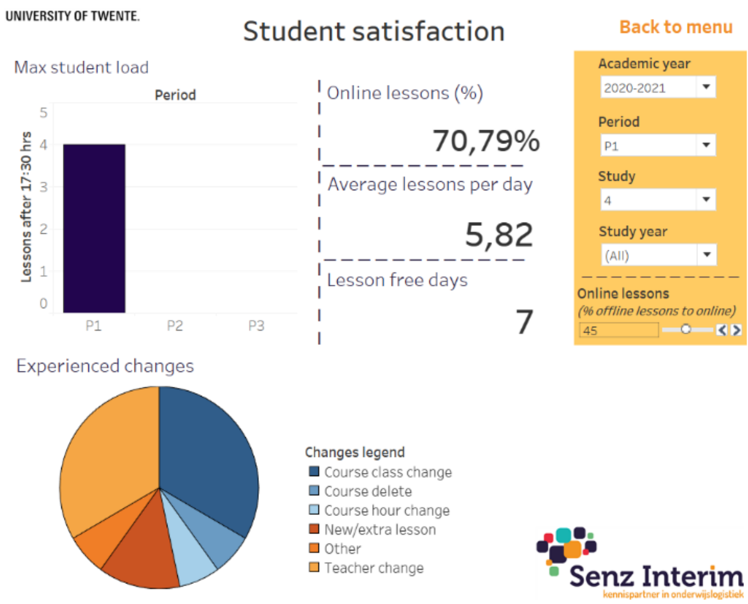


Figure E.26; Online lessons scenario example

Requested occupation versus actual utilisation

Once a user navigates to the ‘Requested occupation versus actual utilisation’ dashboard from the menu, the dashboard sheet seen in Figure E.27 can be seen. This dashboard sheet visualises the KPIs within the category requested occupation versus actual utilisation. First of all, the student presence per course number is visualised for three different years (2017, 2018 and 2019) with the use of a line graph for multiple courses. Course number 1 implies the first lesson of a certain course, course number two the second lesson etcetera. Within this KPI, one is able to get insight into trends regarding the number of students that are present during the timespan of a course. Furthermore, the number of course registrations, asked seats and capacity of the assigned classroom are visualised in a bar chart at the bottom of the dashboard. This is once again shown for three years.

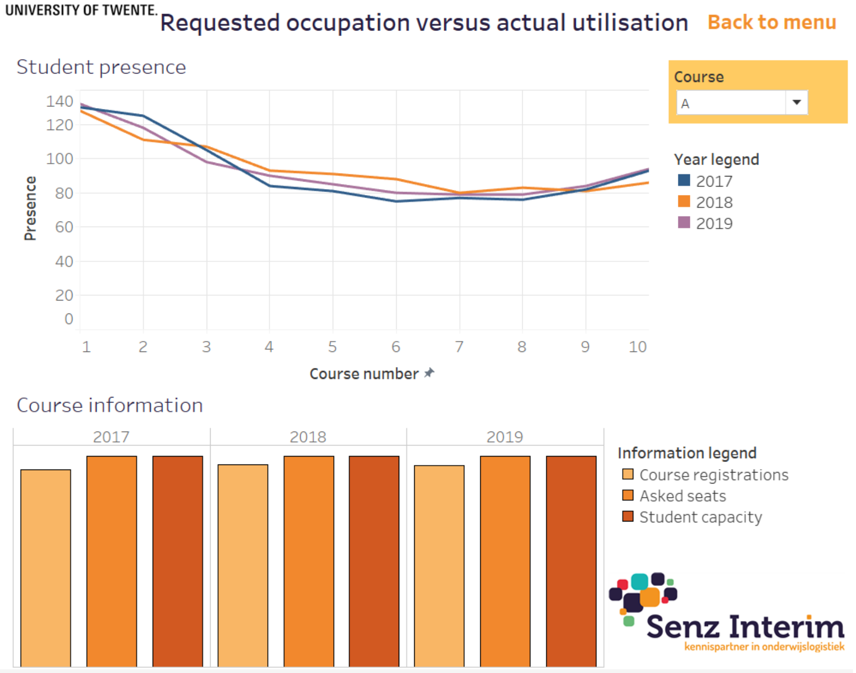


Figure E.27; Requested occupation versus actual utilisation dashboard sheet

One is able to filter on different courses, namely ‘A’, ‘B’, ‘C’ and ‘D’, which can be done by clicking the ‘Course’ filter at the top right of the dashboard. Once interacting with the filter, a dropdown menu will pop up from which a course can be selected (see Figure E.28). Once a course is selected, the student presence and course information regarding the selected course will be shown on the dashboard.

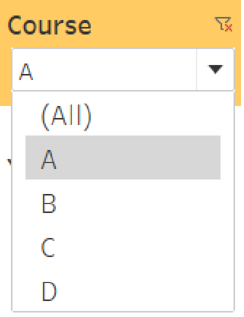


Figure E.28; Course filter

Specific numbers and details about the student presence KPI (measurements of actual numbers) can be seen once a user hovers its mouse over the line graph at the top of the sheet. A tooltip will occur from which a user can see the numbers regarding students present in more detail. An example regarding this can be seen in Figure E.29. Furthermore the specific numbers regarding the course information (registrations, asked seats and capacity of assigned classroom) will be visible once a user hovers its mouse over the course information bar chart. Once again, a tooltip will pop up presenting the course information in numbers. An example of this can be seen in Figure E.30.

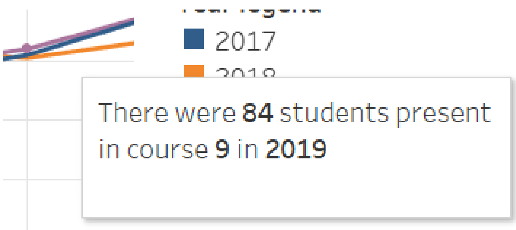


Figure E.29; Tooltip actual measurements example

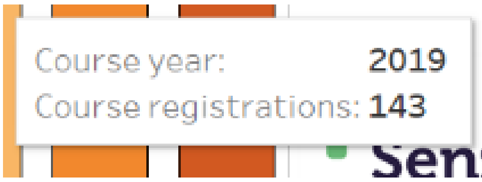


Figure E.30; Tooltip course information example

Registrations academic year

The last dashboard sheet named 'Registrations academic year' consists of the KPIs within the category registrations academic year and can be seen in Figure E.31. First, the total number of registrations is visualised by means of a line graph at the top of the dashboard. One is able to see the change in student registrations over the past five years. In addition, a trend line is implemented within this graph to foresee the trend and possible growth of registrations. Besides, the number of dropouts of the past couple of years is visualised with the use of a line graph as well as the number of first year students.

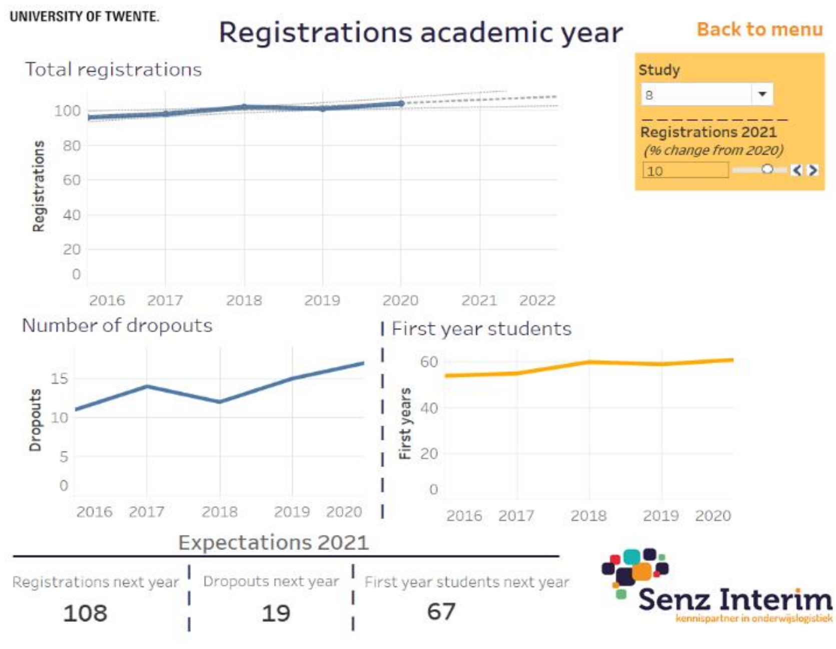


Figure E.31; Registrations academic year dashboard sheet

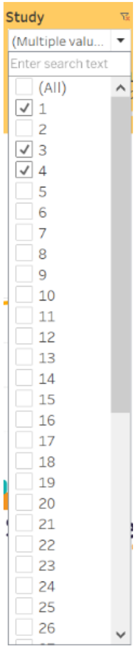


Figure E.32; Multiple study filter

All of the KPIs visualised can be filtered among different studies, moreover multiple studies can be selected at one with a multiple value dropdown filter seen in Figure E.32. Finally, the expectations of next year (2021) can be seen at the bottom of the dashboard. These expectations consist of the number of registrations, dropouts and first year students of next year. The numbers get affected by a change in the what-if scenario within this dashboard that can show the expectations of next year if the percentage of registrations increases or decreases from 2020. This scenario can range from -30% till +30% with steps of 1%. An example of the impact of a change in this what-if scenario in the same context as Figure E.31 can be seen in Figure E.33, where the registrations of the upcoming year is said to decrease with 25%.

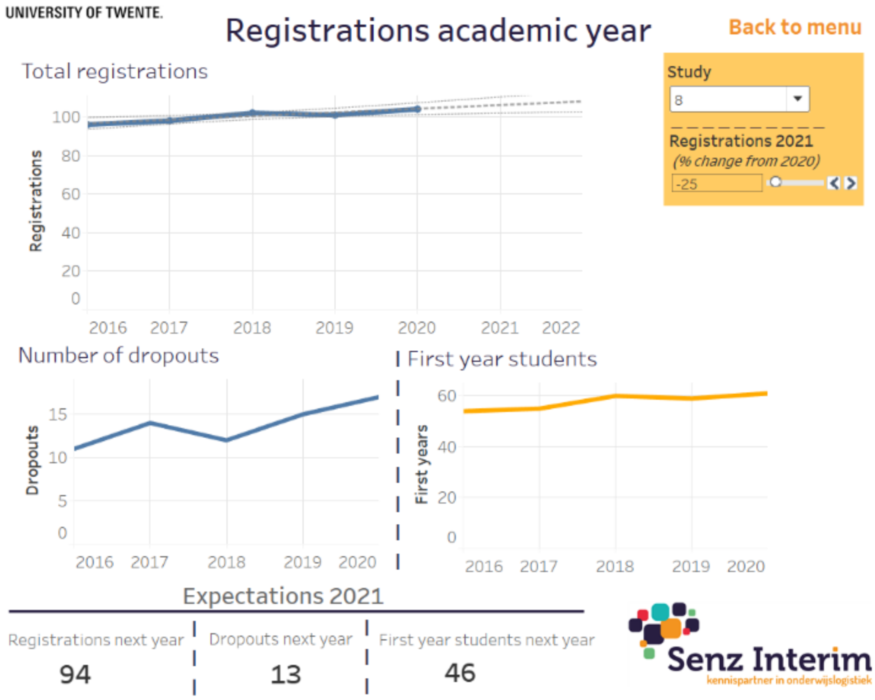


Figure E.33; Registrations 2021 scenario change example