Bachelor Thesis

IMPROVING SCIENTIA'S TIMETABLING USING KEY PERFORMANCE INDICATORS

A case study at Utrecht University for Scientia

Albert Simons
Industrial Engineering & Management
Faculty Behavioural Management and Social Sciences

Examination Committee:
DR. P.C. Schuur
IR. H. Kroon

External Supervisor:
Robert-Jan Bulter MSc -
Head of European Business

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FOREWORD

In front of you lies the result of my bachelor thesis at Scientia. With this report, I conclude my bachelor Industrial Engineering & Management. This was a great period in which I got to know a lot of awesome people and in which I got to study many interesting courses and learnt a lot of important lessons. Next to these great moments, I also experienced some tougher periods near the end of the bachelor. I would like to thank my mother, father and brother for helping me through these rough times.

I also want Robert-Jan Bulter for the endless help he provided during this research.

At last I would like to thank Peter Schuur for his supervision and support.

Albert Simons
Enschede, December 2018

MANAGEMENT SUMMARY

In this paper a timetabling problem for higher education is discussed. The paper zooms in on the timetabling problem faced by Scientia, which is a market-leader in academic timetabling & resource scheduling software with “Syllabus Plus Anywhere”. Scientia currently envisions a new way of scheduling. This involves the use of key performance indicators (KPIs) to measure the performance of a timetable as starting point. The Syllabus Plus user can appoint weights to these KPIs and Syllabus Plus will create a timetable. To implement this new way of scheduling, Scientia wants to know if their current set of KPIs is sufficient.

To get more insight into Scientia’s new way of scheduling, the paper focusses on a case study at Utrecht University (UU) and state the research question: W*hich set of timetable KPIs does Scientia need to offer to fit the objectives of Utrecht University*? This research question is split into four sub-questions:

1. *What are the timetabling objectives of Utrecht University?*
2. *With which KPIs are these objectives measured?*
3. *To what extent is the current set of KPIs from Scientia sufficient?*
4. *How should Scientia adapt their set of KPIs to fit a possible gap?*

To answer these questions, we create a theoretical framework. The existing timetabling objectives in literature as well as KPIs are discussed in this segment. To understand the use KPIs for scheduling one has to understand the underlying relational database on which the KPIs are based. Therefore, relational databases is also briefly discussed. After the theoretical framework has been established, we perform a qualitative research at UU by means of semi-structured interviews with three stakeholders of the timetabling process.

In this research, we found that KPIs are structured into four categories: students, teachers, organisation and costs. When compared to Scientia’s set of KPIs, we can define fifteen of these KPIs that cannot be directly connected to Scientia’s set of KPIs, three KPIs that can partly be connected and two KPIs that are already defined in Scientia’s list of KPIs. Finally, there is a discussion on the gap between the KPIs of UU and the KPIs of Scientia, by showing how the category of student KPIs can be realized within Scientia’s relational database. Three new KPIs are found that can be added to the existing set of KPIs of Scientia:

1. *Completeness of the timetable*: a KPI that measures the completeness of all activities in the timetable database. Based on this completeness and the time till the start of the activity, this KPI can measure how complete a timetable is at a given moment. The ‘completeness’ can differ between courses and faculties. No additional data is needed.
2. *Communication of timetabling changes*: this KPI measures the time between the communication of a change in the timetable and the planned time of the activity in question. Ideally, we would make a distinction between a change in time, a change in location or a cancellation, but additional variables are needed in the database.
3. *Travel time*: With this KPI, we measure the travel time between subsequent activities and return a value based on the length of this travel time and the time between the activities. No additional data is needed, but the user of Syllabus Plus should define zones and connect those to locations.

We recommend Scientia to add these KPIs to their existing set. We also recommend Scientia to conduct further research in the area of categories of teachers, organisation and cost.

Concluding, the contribution of this paper is threefold. First of all, it provides a clear description of the time tabling problem faced by high education institutions. Secondly, it provides a case study zooming in on the timetabling demands of a particular institution: UU. Finally, the paper provides Scientia with a recommendation on how they could update their set of KPIs, based on their relational database, to satisfy these demands.

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LIST OF ABRREVIATIONS

UU	Utrecht University
KPI	Key Performance Indicator
RDBMS	relational database management system

1 INTRODUCTION

In the framework of the bachelor Industrial Engineering and Management, I performed research at Scientia into the Key Performance Indicators(KPIs) on timetabling that Scientia should offer their users.

1.1 Scientia's timetabling problem

This research is done in collaboration with Scientia, market-leader in academic timetabling & resource scheduling software. In 2017, Scientia announced a new version of its current planning and scheduling solution "Syllabus Plus Anywhere". Built on this new platform, Scientia is developing and innovating their scheduling solution "Timetabler". The timetables are currently based on different parameters that are determined by Scientia, but manipulated by Scientia's users. In the end it is the user that is accountable for the outcome of the timetable. After a timetable has been made, the customer can determine if the quality and goals of this timetable are met. Scientia's customers can determine the quality by, for example, analysing a polar diagram that Scientia (Figure 1). This polar diagram is based on fourteen predefined KPIs.

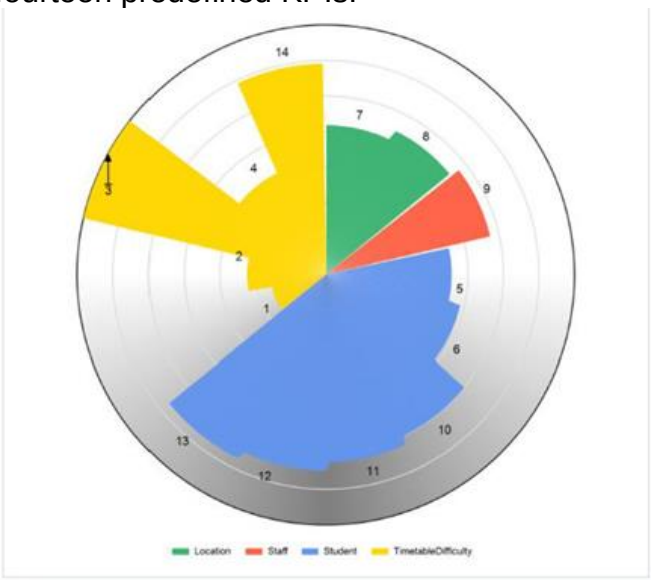

FIGURE 1 POLAR DIAGRAM OF THE KPI RESULTS

As a part of the improvements that are being made, Scientia is planning to change the methodology of how a timetable is made. Instead of influencing the parameters of the scheduling engine before the scheduling is done, the idea is that the desired outcome is determent based on KPIs accordingly the scheduling engine autoschedules the new timetable based on the KPIs. This new way of timetabling will change the way Syllabus Plus is used. The timetabling process will be more automated and output driven. Currently the user is defining the scheduling preference, scheduling and reviewing the end results. Scientia is turning the scheduling process around. The user will now start by defining the end result by

means of indicating various quality measures or KPIs. Accordingly the scheduling engine is doing the rest.

To make this change possible, the quantification of the quality of the timetable will become more important. Moreover, the number of quality measures needs to be expanded. Quality will not be an optional comparison at the end of the timetabling process, but will be defined before the start of the creation of every timetable. With quality at the start of each timetabling process, Scientia has to have a clear idea of what 'quality' means for their customers and how these different parts of 'quality' should be measured. The problem is that the quality of a timetable is not a given fact and depends on many different aspects. Opinions about which aspects are necessary to determine the quality often differ between institutes, faculties and even between people within a faculty.

Together with a group of clients, Scientia has created a set of KPIs that indicates the quality of a timetable. Scientia is keen to know if this set of KPIs is still sufficient for their costumers to measure the quality of their timetable. The research goal is: *Get a better understanding of the timetabling objectives of Scientia's customers and find out if the current set of KPIs is sufficient.*

1.2 Research question

To get a high customer satisfaction with Syllabus Plus Anywhere, Scientia wants to know if their current set of KPIs is sufficient to fit the customer's objectives. In this research we compare this set of KPIs with the objectives of Scientia's users. To gain enough in-depth knowledge and to finish this study within a reasonable timeframe, we had to narrow down the scope to one or two institutions. With help of Scientia, we concluded that Utrecht University (UU) and Radboud University would best represent Scientia's users. We did a preliminary research at those universities to study the role of objectives in the timetabling process. We decided to test the current set of KPIs from Scientia at UU. We cover more of this preliminary research in chapter 3.

In this paper we will make a case study out of UU and see how the KPIs from Scientia compare to the objectives and KPIs that UU has found in their research. Therefore, the main research question states: W*hich set of timetable KPIs does Scientia need to offer to fit the objectives of Utrecht University*? This question will be divided into four sub questions:

1. *What are the timetabling objectives of Utrecht University?*

The timetabling objectives of UU are the basis to answer the research question. We will need to understand what is important to the users of Scientia's product 'Syllabus Plus'. In this case we need to know which aspects define the quality of their timetable and timetabling process.

2. *With which KPIs are these objectives measured?*

When the objectives are clear, we should have a clear understanding of how these objectives are or can be measured with KPIs. Does UU currently have a set of KPIs or do they have an idea of how their objectives can be measured? The objective of this sub question is to get a clear set of KPIs that would be ideal for UU, not taking into account whether these KPIs are realistic for Scientia or directly connected to what Scientia can offer.

3. *To what extent is the current set of KPIs from Scientia sufficient?*
When this set of KPIs from UU is clear we can compare this set to the set of KPIs that Scientia is currently offering. To do this we also need to have a closer look at how the KPIs are generated from the reporting database. After that we will look for the similarities between these sets and in particular the differences.

4. How should Scientia adapt their set of KPIs to fit a possible gap?
If there are differences between the sets of KPIs? We will check whether Scientia's set needs to be adapted. If this is the case, we will look at the feasibility of this adaption. This requires checking whether the data that is necessary for the new possible KPI is available in the Syllabus Plus database.

1.3 Research design

We follow certain steps to answer the research question that we stated in the previous section. We create a theoretical framework in chapter 2 that, first of all, provides information from current literature about KPI, both in general as well as in the field of timetabling in higher education. Secondly, we study the current list of KPIs that Scientia provides. Thirdly, we address literature to get a better understanding of the feasibility of KPIs and how they rely on certain data. As fourth part of the theoretical framework, we study how Scientia's database is constructed. This is necessary to check whether Scientia can provide the KPIs that UU desires. Moreover, it is necessary to check the feasibility of the newly proposed KPIs. Therefore, we particularly zoom in on how KPIs in this database can be extracted. In chapter 3, we discuss the methods used for this research. We explain why Utrecht University has been chosen as a case study. Furthermore, we elaborate on why we did a qualitative research with semi-structured interviews and how the theoretical framework helps us answering the research question. In chapter 4, we answer the sub-questions based on the interviews at UU, the theoretical framework and the information that was provided by Scientia. Chapter 5 consists of the conclusions of this research. We answer the research question, based on the answers of the sub-questions in chapter 4 and give recommendations to Scientia. In chapter 6 we discuss improvements to the research, limitations we encountered and possible additional research.

2 THEORETICAL FRAMEWORK

In this chapter we explain the theoretical framework. We will start with the definition of a KPI and how, in general, KPIs are used in timetabling. Consecutively we will describe the KPIs used by Scientia. The feasibility of the KPIs is determined by the availability of the data necessary for computing the KPIs. The feasibility and the reporting database are explained at the end of this chapter.

2.1 Key Performance Indicators in timetabling

KPIs are a summarized set of the most important measures that inform managers how well an operation is achieving organizational goals (Boddy, 2008). It is a way to measure how you have scored on certain important objectives. It is however important to note that not all Performance Indicators are Key Performance Indicators. Parmenter (2015) states in his book *"Key performance indicators: developing, implementing, and using winning KPIs"* that there are actually types of performance measures: Key Results Indicators (KRIs) that tell you how you have done in a perspective, Performance Indicators (PIs) that tell you what to do and Key Performance Indicators(KPIs) that tell you what to do to increase performance dramatically. Parmenter uses an onion analogy to describe the relationship of these three performance measures (Figure 2). The outside skin describes the overall condition of the onion. However, as we peel the layers off the onion, we find more information. The layers represent the various performance indicators, and the core, the key performance indicators.

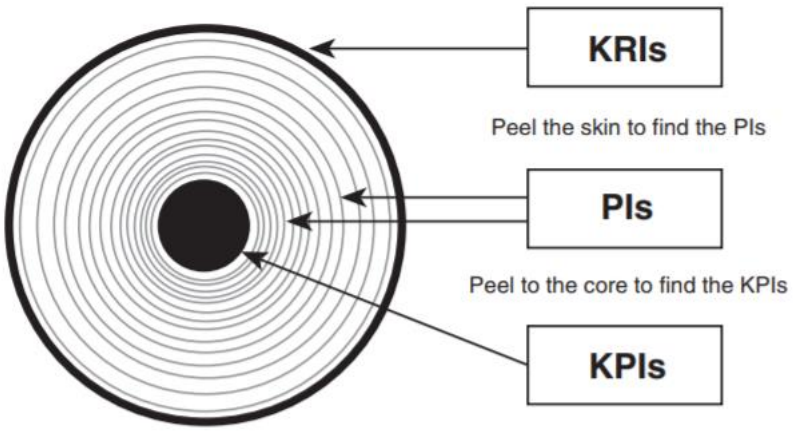

FIGURE 2 THREE TYPES OF PERFORMANCE MEASURES(PARMENTER, 2015)

It is important to keep these differences in mind, especially the differences between KRIs and PIs/KPIs. In this research, we look for a complete set of performance indicators that fits the objectives of UU. Since both UU and Scientia make no distinction between PIs and KPIs, we will not make a distinction either and use "Key Performance Indicators" as a collective term.

Now that “KPIs” have been defined, we will look at existing literature on KPIs in timetabling. The field of timetabling in higher education has gained more attention since the Second International Timetabling Competition (Di Gaspero, McCollum, & Schaerf, 2007). For this competition, research was done to study the possible timetabling objectives that competitors should take into account. Bonutti, De Cesco, Di Gaspero, and Schaerf (2012) have added to this research and created a list of timetable constraints in higher education so that other researches could use this as a starting point. They distinguished between hard constraint and soft constraints. Hard constraint are conditions that have to be met in a timetable. Soft constraints are measurable conditions that do not necessarily have to be met, but determine the quality of a timetable(Bonutti et al., 2012). Based on that definition, we can assume that a soft constraint is basically the same as a KPI. Every institution has its own priorities and objectives, so every institution attaches a different value to each soft constraint.

Bonutti et al. (2012) states that there are four main hard constraints:

- *Lectures*: All lectures of a course must be scheduled, and they must be assigned to distinct periods. A violation occurs if a lecture is not scheduled or two lectures are in the same period.
- *Conflicts*: Lectures of courses in the same curriculum or taught by the same teacher must be all scheduled in different periods. Two conflicting lectures in the same period represent a violation.
- *Room Occupancy*: Two lectures cannot take place in the same room and period. Two lectures in the same room at the same period represent one violation.
- *Availability*: If the teacher of the course is not available to teach that course at a given period, then no lecture of the course can be scheduled at that period. Each lecture in a period unavailable for that course is a violation

The reason we show hard constraints in this theoretical framework is that we should be able to distinguish the compulsory hard complaints from the soft constraints or KPIs.

Bonutti et al. (2012) states that there are ten soft constraints that should be considered:

- *Room Capacity*: For each lecture, the number of students that attend the course must be less than or equal the number of seats of all the rooms that host its lectures.
- *Minimum Working Days*: The lectures of each course must be spread into a given minimum number of days. Each day below the minimum counts as 1 violation.
- *Isolated Lectures*: Lectures belonging to a curriculum should be adjacent to each other (i.e., in consecutive periods). For a given curriculum we account for a violation every time there is one lecture not adjacent to any

other lecture within the same day. Each isolated lecture in a curriculum counts as 1 violation.

- *Windows*: Lectures belonging to a curriculum should not have time windows (i.e., periods without teaching) between them. For a given curriculum we account for a violation every time there is one windows between two lectures within the same day. Each time window in a curriculum counts as many violation as its length (in periods).
- *Room Stability*: All lectures of a course should be given in the same room. Each distinct room used for the lectures of a course, but the first, counts as 1 violation.
- *Student Minimum Maximum Load*: For each curriculum the number of daily lectures should be within a given range. Each lecture below the minimum or above the maximum counts as 1 violation.
- *Travel Distance*: Students should have the time to move from one building to another one between two lectures. For a given curriculum we account for a violation every time there is an instantaneous move: two lectures in rooms located in different building in two adjacent periods within the same day. Each instantaneous move in a curriculum counts as 1 violation.
- *Room Suitability*: Some rooms may be not suitable for a given course because of the absence of necessary equipment (projector, amplification, . . .). Each lecture of a course in an unsuitable room counts as 1 violation.
- *Double Lectures*: Some courses require that lectures in the same day are grouped together (double lectures). For a course that requires grouped lectures, every time there is more than one lecture in one day, a lecture non-grouped to another is not allowed. Two lectures are grouped if they are adjacent and in the same room. Each non-grouped lecture counts as 1 violation.

These soft constraints or KPIs give an indication of what timetabling aspects are important to different institutions in higher education. These ten constraints give us a better insight in the possible objectives that the users of Syllabus Plus have.

2.2 Key Performance Indicators used by Scientia

Now that we studied some soft constraints or KPIs used in literature, we should study and list the KPIs that Scientia offers. Scientia offers the following set of KPIs to their users to see the characteristics of the schedule they have made:

- *Availability of appropriate space*: Any measure of the utilization of space has meaning only in the context of the difficulty of satisfying the requirements for space. For example, consider a case where the majority of teaching activities require rooms that will accommodate classes of size 20 or of size 100. If the capacity of available rooms is 18, 40, 80, 180 then it will be necessary to accommodate activities with 20 students in rooms of capacity 40 and activities with 100 students in rooms of capacity 180. Even if such rooms were used 100% of the time, the rate of utilization could never be greater than 50% or 56% respectively. The measure of availability of appropriate space is an indicator of how far the available space differs from

the requirement for space. The higher the value the more difficult it will be to accommodate the required activities using the available space.

- *Availability of appropriate staff*: The ability to satisfy the requirements for staff for all of the activities that need to be scheduled will have an impact on other characteristics of the timetable. For example, if a set of activities can only be delivered by one member of staff they are automatically constrained by the availability of that member of staff and cannot be taught concurrently. As with the previous measure, a high value indicates a high level of difficulty, each activity has a requirement that can only be satisfied by one or a few members of staff.
- *Concentration in the week*: If the activities that need resources are spread evenly across the week then it will be relatively easier to satisfy the requirements, whereas a high concentration of demand will inherently lead to inefficient usage of resources. It will require sufficient resources to meet the demand at peak times while leaving those resources unused at other times. A high value indicates a high level of difficulty in satisfying the requirements.
- *Concentration in the year*: As with concentration in the week, concentration of demand within the year will result in a requirement for sufficient resources to satisfy demand in peak weeks so that the resources will inevitably have a low rate of utilization when demand is lower. A high value indicates a high level of difficulty in satisfying the requirements.
- *Flexibility of module choice*: A timetable that offers no choice to students so that all students on a programme of study take the same modules will have a low value, whereas a timetable that offers multiple different ways to complete the programme will have a high value. Greater choice may be seen as good from the student perspective but will make solving the scheduling problem more difficult.
- *Flexibility of timetable*: Given a particular combination of modules, a timetable that allows only one way for a student to attend all the required activities will give a low value, whereas a timetable that allows multiple different ways to attend all the activities (i.e. a choice of different days / times) will give a high value.
- *Consistency of student timetable*: This measure compares the pattern of a student's timetable in a given week with the pattern for other weeks, measuring consistency of the timing of activities as well as their location. The more consistent the timetable is from one week to the next the higher the value will be.
- *Spread of student timetable*: A student might have a timetable that is spread evenly across the available week or one that is heavily concentrated into a few days of the week. Neither scenario is good or bad, per se. A full –time student might prefer activities that are evenly spread whereas a student who also has a job or child-care commitments might prefer one that is concentrated. A high value indicates that the activities are evenly spread. A low value indicates that they are concentrated.
- *Grouping of student activities*: Once a student has travelled to campus it might be considered efficient to keep them there for a group of activities

rather than having large gaps between activities. There will, of course, be a limit beyond which such grouping of activities would be counter-productive. This measure compares the current shape of a student's timetable with an ideal of activities being bunched into a number of tightly packed groups. A high value indicates that the timetable is close to the ideal.

- *Constraints met for students*: A common way to measure the student-friendliness of a timetable is to define a set of constraints that should be met. This measure shows the extent to which a standard set of constraints is met for students. A high score indicates that the constraints are met for many students.
- *Spread of staff timetable*: As with students, a member of staff might have a timetable that is spread evenly across the available week or one that is heavily concentrated into a few days of the week. A high value indicates that the activities are evenly spread. A low value indicates that they are concentrated.
- *Grouping of staff activities*: A member of staff who travels to campus to deliver teaching might consider that it is more efficient to deliver a block of teaching while there, rather than having large gaps between timetabled activities. There will, of course, be a limit beyond which such grouping of activities would be counter-productive. This measure compares the current shape of a staff timetable with an ideal of activities being bunched into a number of tightly packed groups. A high value indicates that the timetable is close to the ideal.
- *Balancing of staff load*: This value is a measure of how evenly the total teaching workload is spread between the available staff. In the case where every member of staff has the same share of the teaching workload the value will be high. In the case where there is a wide variation with some staff teaching much more than average and some teaching much less than average, the value will be low.
- *Constraints met for staff*: As with the equivalent measure for students, the value is a measure of the proportion of staff for whom a set of constraints are met where those constraints represent traits that are considered staff-friendly.
- *Frequency of room use*: This value measures the proportion of the available time that rooms are in use. The single measure is an average across all rooms with a high value showing that rooms are in use most of the time and a low value indicating that they are often empty.
- *Space occupancy*: When a room is in use it may be filled to capacity or have only a fraction of the seats taken. This value is an averaged measure of the extent to which rooms are filled, considering only the times when they are in use. A high value indicates that rooms are often close to full.
- *Within target hours*: It is assumed that each institution will have a target set of hours in the week within which they wish to timetable all activities. This value is a measure of the extent to which activities are, in fact, accommodated within those target hours.

- *Space Utilisation*: This measurement takes the frequency of room use and multiplies this with the occupancy rate. An ideally high space utilisation rate requires that rooms are continuously used and while they are used they are also fully occupied.

2.3 Feasibility KPIs

A KPI is a way to measure certain objectives. Each KPI contains at least one variable that is used as input for generating a number that should show how well you scored in a that certain objective. A KPI runs on a given dataset or database and the needed variables are certain parts of this set. For a KPI to be feasible, those certain parts of the stored data have to be available. To see if this data is in fact available, we should understand how we a database is built up and where we can find the necessary data.

In most cases the data store, that is used for calculating KPIs, is a relational database management system (RDBMS). Scientia's reporting database is such a relational database as well. A RDBMS is a software system to maintain relational databases. The relational database is a database management system based on the relational model that was invented by Codd (1970). He invented the relational database to protect future users of large data banks from having to know the internal representation of the data, i.e. how the data is organized in the machine. Codd (1970) claims the relational view of data to be superior in several aspects with respect to the conventional network or graph models, which are non-inferential. First of all, a relational model allows describing the data using its natural structure only. This means we do not need to impose any additional structure that would be necessary for machine representation. Secondly, the relational view provide a basis for treating consistency, derivability, and redundancy of relations. Thirdly, it allows to clearly evaluate both the logical limitations and the scope of present formatted data systems.

In a relational model all data is represented in terms of different tables. The different tables are then connected to each other by means of relationships. These relationships are logical connections based on the interaction between the tables. The tables themselves are called relations and usually describe one entity type, such as 'staff', 'location' or 'activity'. However, tables themselves can also contain information on the relationship between different tables. The tables consist of rows and columns. In the literature the rows are often called tuples or records. Each row is an instance of the broader entity described by the table. The columns are called the attributes as they contain information corresponding to the instances captured by the rows.

With the relational model, we can build a relational database that is based on tables and relations. Although a relational database might look complex due to many different tables and relations, it has a clear structure. The user of the database can access the information in the database by using information

contained by both the tables themselves and the relationships between different tables.

Due to the clear structure of the RDBMS, a database schema diagram can be used as a graphical depiction of the structure of the RDBMS. In this schema diagram all tables and relations are clearly visualized.

The feasibility of de KPIs is determined by the question: “Is the data that is needed for calculating the KPI, stored in the reporting database of Scientia”? We can answer this question by analysing the database schema diagram of Scientia. In the next section this analysis will be performed on a small part of the schema.

2.4 Database schema diagram Scientia

As mentioned in the previous section, a database schema diagram can be used to visualize a relational database. Scientia made such a diagram that contains all available data in tables and shows the relation between these tables. It shows what data is available regarding the activities, staff, students, locations, etc. A complete Database Schema Diagram of the reporting database is attached in the Appendix. A small part of this Schema is shown in Figure 3 as an example of how to interpret such a schema.

In this schema there are three tables and these tables are related to each other. The table ‘Activity’ contains all activities (one tuple per activity) with all the characteristics per activity. Recall that the rows correspond to a single instance, in this case activity, and the columns are the characteristics. For example, the name of the Activity, a description, the ‘startdate’, the ‘enddate’ and the duration. The table ‘Staff’ contains all staff members (one tuple per staff member) with all the characteristics per activity. For example, the name, the department, e-mail addresses, etc. The table ‘Staff_DoubleBooking’, describes the relation between an ‘Activity’ and a ‘Staff’ member. One staff member can contribute to 0 to *n* Activities. And the other way around: one activity can be carried out by 0 to *n* staff members. The characteristics of this relation is the week and period.

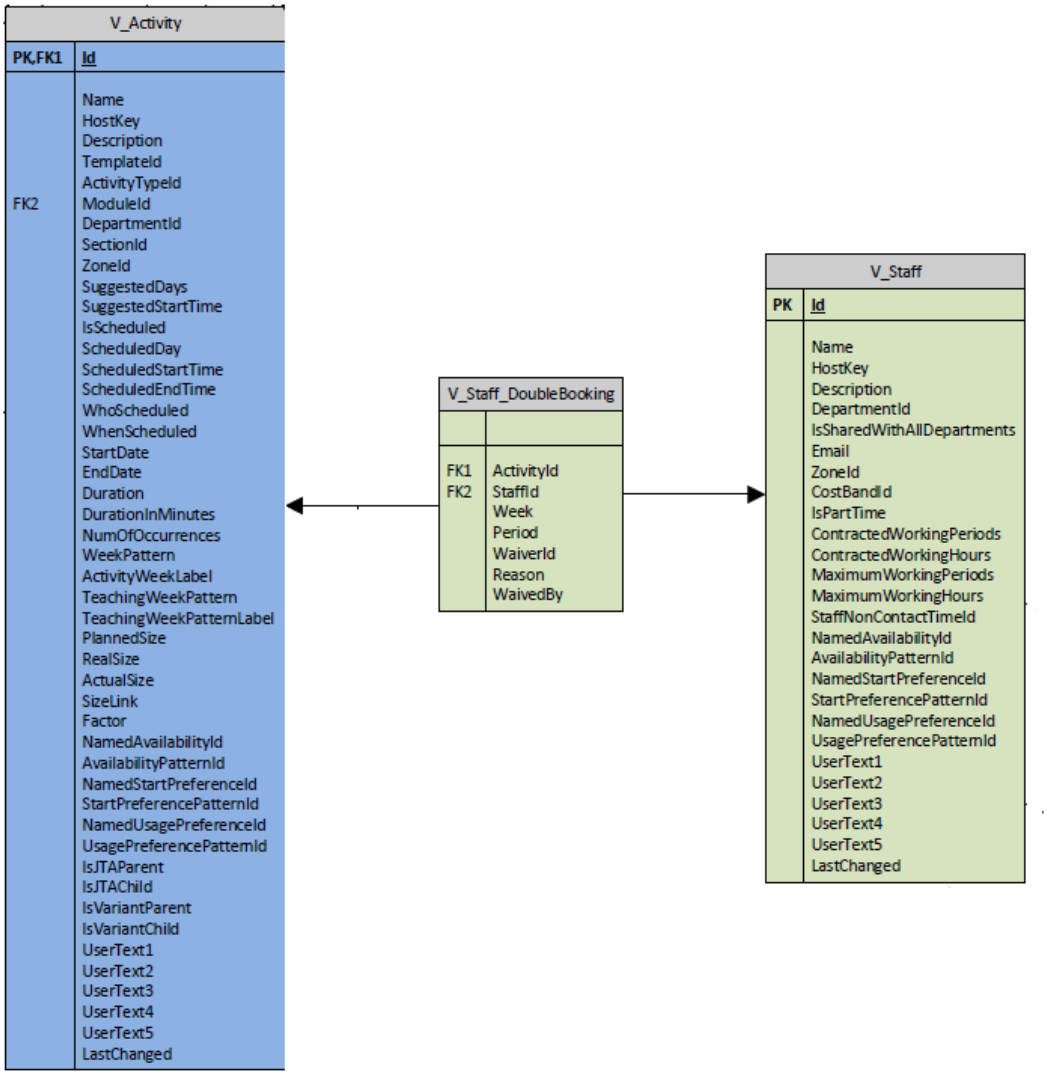

FIGURE 3 EXAMPLE OF HOW TO INTERPRET A DATABASE SCHEMA DIAGRAM

In this chapter we established the theoretical framework for this research. We discussed KPIs and the main KPIs that are used in timetabling. We also showed the KPIs used by Scientia. Next, we studied how the feasibility of a KPI can be measured and what the role of a RDBMS is. At last, we showed how a database schema diagram from Scientia could be used study the feasibility of possible new KPIs.

3 METHOD

In this chapter we explain how this research was done and what methodology was used. We explain how we attempted to realize the goal of this research: *Get a better understanding of the timetabling objectives of Syllabus Plus' users and find out if the current set of KPIs is sufficient.*

3.1 Case study

To do so we need a better understanding of why the current set of KPIs might not be sufficient for Scientia. To get a better insight into this question, we decided to use a case study. Yin (2003) states that case studies are best used when a 'how' or 'why' question is posed, and the researcher can have no or almost no control over the behavioural event. A case study should fit well within this research, as we also pose a 'why' question and have no control over the choosing process of objectives of Scientia's users. By choosing for a case study, we defined a clear and achievable scope where we focus on a single case. The advantage of this focus would be that we are able to obtain more in-depth knowledge on a particular organization or phenomenon and that the chance is greater that the research will be easier to accept(Van Tulder, 2012). An important disadvantage of a case study is that case studies generally score low on validity and reliability(Gibbert, Ruigrok, & Wicki, 2008). This could make it harder to come up with generalizations that conform with other users of Syllabus Plus as well. Eisenhardt and Graebner (2007) state that the best way to counteract this problem is finding a case study that best represents a problem or issue. For this research we looked for a Syllabus Plus user that would be representative of the problem that Scientia has.

To find a Syllabus Plus user that would be suitable for the case study, we did a preliminary study at Radboud University and Utrecht University. Both universities seemed representative out of the other users of Syllabus Plus, because they are both universities of considerable size that are also long time users of Syllabus Plus. The considerable size is important, because large institutions might experience extra problems and objectives in their timetabling process compared to smaller institutions. The downside here is that we ignore problems and objectives that are inherent to smaller institutions. We chose for a university, because Scientia pointed out that university timetables are generally more complex. We chose for a long time user of Syllabus Plus for the sake of having a lot of experience with the product and ruling out any problems concerning the implementation of Syllabus Plus. In this study we interviewed both institutions.

The goal of the interviews was to get a clear picture of how both institutions used Syllabus Plus, how they measured the quality of their timetable and how they implemented quality. The role of quality of a timetable in an institution is important for this research, because this should also give a good indication of how interested the institution is in the research and how well the research fits with the institution in question. With the results of the preliminary study, we decided to partner up with

Utrecht University for the case study in this research. The deciding factor in this decision was that UU was in the process of improving their timetabling process. This meant that they were already thinking about what was important to them and which objectives could be meaningful in their timetabling process. As we determined that a case study at UU would be the best method for this research, we also determined that this research would have to be qualitative. Qualitative research is primarily exploratory research with the purpose of understanding underlying reasons. This fits well with the case study that we described in the previous paragraphs.

3.2 Research question

In this research and case study we try to answer the research question: *which set of timetable KPIs does Scientia need to offer to fit the objectives of Utrecht University*? This question has been divided into four sub questions that will form the foundation of this research. The four sub questions are:

1. What are the timetabling objectives of Utrecht University?
2. With which KPIs are these objectives measured?
3. To what extent is the current set of KPIs from Scientia sufficient?
4. How should Scientia adapt their set of KPIs to fit a possible gap?

To answer these questions, we first had to study the objectives of UU. To fill this knowledge gap, we chose for a qualitative research by means of a case study at Utrecht University.

Lewis (2015) states that a case study is an example of a qualitative research. As we determined that a case study would be the best method for this research, we also determined that the research would have to be qualitative.

3.3 Data collection method

The next step was determining the method to collect data about the timetabling objectives of UU. Common data collection methods for a qualitative study are focus groups, individual interviews and observations. In this case study we chose for individual interviews. An advantage of an individual interview is that it is an excellent means of checking whether your research approach is solid or not (Van Tulder, 2012). This is also the main advantage of why we chose for individual interviews. Disadvantages that Van Tulder (2012) describes are that only a limited number of interviews are feasible, it might take a lot of time to get in touch with the relevant responders and that often you have to promise confidentiality of the interviews. We decided that these disadvantages were not of such large size that we would have to favour another data collection method.

For this interview, we will make use of the techniques for identifying objectives that Keeney (1994) defines in his paper. This process usually involves discussions with relevant decision makers and stakeholders. Keeney developed a list with a number of techniques for identifying possible objectives(see Figure 4). These

techniques often lead to a redundant list, but it is easier to recognize redundant objectives than missing objectives. We will not make use of all techniques.

1. **Develop a wish list.** What do you want? What do you value? What should you want?
2. **Identify alternatives.** What is a perfect alternative, a terrible alternative, some reasonable alternative? What is good or bad about each?
3. **Consider problems and shortcomings.** What is wrong or right with your organization? What needs fixing?
4. **Predict consequences**. What has occurred that was good or bad? What might occur that you care about?
5. **Identify goals, constraints, and guidelines.** What are your aspirations? What limitations are placed on you?
6. **Consider different perspectives.** What would your competitor or your constituency be concerned about? At some time in the future, what would concern you?
7. **Determine strategic objectives.** What are your ultimate objectives? What are your values that are absolutely fundamental?
8. **Determine generic objectives.** What objectives do you have for your customers, your employees, your shareholders, yourself? What environmental, social, economic, or health and safety objectives are important?
9. **Structure objectives.** Follow means-ends relationships: Why is that objective important? How can you achieve it? Be specific: What do you mean by this objective?
10. **Quantify objectives.** How would you measure achievement of this objective? Why is objective A three times as important as objective B?

FIGURE 4 TECHNIQUES FOR IDENTIFYING OBJECTIVES(KEENEY, 1994)

For this interview, we deemed semi-structured interviews the best option to best understand the timetabling objectives of UU. A fully structured interview would be less flexible than an unstructured interview. This would not be favourable since you might lose valuable information, because the expert only reacts to the given questions. An unstructured interview might however result in a situation where not all answers are answered. We meet in the middle with the semi-structured interview. Based on the ten techniques that we see in Figure 4, we formulated a strategy for the semi-structured in-depth interviews that would be held with some of the stakeholders in the timetabling process. This semi-structured would consist

of some points, which would function as directions in the interviews and would also be the bare minimum that should be answered. With these points we create a framework for the interview.

In the first phase of the interview we start with a short introduction about the research we are conducting and the goals we have. In the second phase we focus on the functions of the interviewee and what his or her role is in the timetabling process. This is important for the interpretation of the rest of the interview. With the third phase we ask the stakeholder about the problems and shortcomings in the current timetable and timetabling process. By asking about possible problems, it is easier to identify the origin of objectives further on. In the fourth phase we try to develop a wish list based on the problems that we defined in the previous phase. In the fifth phase we ask the interviewee what his or her strategic objectives are in the timetabling process. This means that we should have a clear view on the absolutely fundamental values and ultimate objectives. When that is clear, we should be able to move on to more specific objectives. In the sixth phase we try to determine the more generic objectives. We try to develop a list with all objectives. After we have done that we ask the interviewee if she can consider different perspectives in phase seven. Timetabling objectives of other stakeholders might be different. We add new found objectives to the list. In phase eight we try to structure this list of objectives and see if that results in new insights. In the ninth and last phase we ask the interviewee how the list of objectives should be quantified. We try to find out how we should measure the objectives and how we can translate the objectives to KPIs. We show a short summary here:

1. Introduction
2. Function of the interviewee and role in the timetabling process
3. Problems and shortcomings in the timetabling process
4. Develop a wish list
5. Strategic objectives
6. Generic objectives
7. Consider different perspectives
8. Structure objectives
9. Quantify objectives

We now have all data to answer the first two sub questions. Based on results of these two sub-questions and the theoretical framework we should also be able to answer the third sub-question: *To what extent is the current set of KPIs from Scientia sufficient?* We compare the current set of KPIs that Scientia offers as shown in the theoretical framework with the KPIs from UU that we found in the second sub-question. After that we answer the fourth sub-question: *How should Scientia adapt their set of KPIs to fit a possible gap?* Here we use the feasibility of KPIs and the database of Scientia as a framework and the results of sub-question three to study the possibilities to fill this gap.

3.4 Data processing

In the interview we tried to go through all nine phases, but also be open for side tracks. The nine phases however create a framework which we can use to process the data from the interviews. With this frame work we already guide the interview in the direction of the results we need for the first sub-question. These results are described in phase six, seven and eight. The phases before that give a context of the given objectives and the last phase should give an answer to the second sub-question.

During the interviews, the answers to the questions were noted in key words and already categorized and structured in these different phases. Miles et al.(1994) describe the first step of data reduction as the process of deciding what should be transcribed and what should be left out. In this research we decided to transcribe all data or information that is relevant to the research question and concerns the timetabling goals of UU. The second step was to group all objectives into categories and compare all interviews. The last step was combining any goals that were similar or almost similar. The result is a list of timetabling goals and KPIs of UU according to all interviewees. This list will be further elaborated in the next chapter.

In this chapter, the methodology of this study is elaborated. We concluded that a qualitative research would be best suited for this study and choose for a case study at UU to achieve the goal of this research. We established the research question: *which set of timetable KPIs does Scientia need to offer to fit the objectives of Utrecht University*? Based on the techniques for identifying objectives(Keeney, 1994), a semi-structured interview was created. After the data processing, a list of timetabling goals and KPIs of UU was created.

4 ANALYSIS

In the chapter we process the results of the interviews and use this in combination with the theoretical framework to answer the four sub-questions. By doing so, we should be able to answer the research question: W*hich set of timetable KPIs does Scientia need to offer to fit the objectives of Utrecht University*?

In section 4.1, we describe the timetabling objectives of Utrecht University that emerged from the interviews. In section 4.2, we study the KPIs that can measure the objectives from 4.1. In section 4.3, we compare these KPIs with Scientia's current set of KPIs. In section 4.4, we study how new KPIs can fill a possible gap.

4.1 What are the timetabling objectives of Utrecht University?

In this section we describe the timetabling objectives which were found in the interviews with three employees of UU that are involved in the timetabling process. For this chapter we use phase one till eight from the interview, where phase one till five gives a clear context for the objectives and phase six till eight should help to answer the question directly. The goal of this sub-question is to understand which parts of the timetabling process are important to UU.

We tried to get a better understanding of the objectives by interviewing Simon Witteveen, Martin Tukker and Miranda van Heesch. All three are staff members of UU who are involved in the timetabling process. They all work at the timetabling department of UU, who are responsible for the functioning of the timetable. They are also responsible for the quality of the timetable and deal with given objectives and possible complaints. Simon Witteveen is an end-user of Syllabus Plus and has a good understanding of how the product works. Martin Tukker is the product specialist of Syllabus Plus at UU. He knows all the options and availabilities of the product. He often deals with the management team of UU and their objectives. Miranda van Heesch leads a team that studies the possibilities of improving the current timetabling process. At the moment of the interview, they were at the start of this study. They already had some thoughts about timetabling objectives and how to measure them.

From the interviews with Simon Witteveen, Martin Tukker and Miranda van Heesch, we created a list with wishes about possible improvements:

1. An increase in the score of the National Student survey in the area of timetabling.
2. The timetabling department would like to have more time between the timetable requests and the deadline that the whole timetable should be ready.
3. An increased focus on the efficiency of the available rooms.
4. A shift in mentality from "creating a workable timetable that is just sufficient" to "creating a good timetable".
5. Changes in timetabling should be communicated earlier.

6. Teachers should not have to change locations so much during the day.
7. Teachers actually use all the rooms that they request. Sometimes they cancel lectures, but do not communicate that to the timetabling department.

This list was used in a later stage of the interviews and gives us an idea of the opinions on timetabling.

The strategic objectives that came forward from the interviews, all focused on three stakeholders: the students, the teachers and the board of directors. The most important aspect for students and teachers is that they all have a timetable that is manageable, complete and on time. The most important aspect for the board of directors is that the room frequency rate should be as high as possible and at least above 70%.

In the next paragraph, we have already structured the objectives based on the interview. The objectives were divided into four aspects: Students, Teachers, Organization and Costs.

The first aspect in timetabling that emerged from the interviews concerns the students of UU. It is important for UU that students are satisfied with their timetable. This part has especially been important since the results of the last National Student survey came out. Last year, UU scored lower on the timetabling component than the year before(Studiekeuze123, 2018). Student satisfaction, according to the interviews, includes a clear and timely publication of the timetable and possible last-minute changes. This way a student knows what he or she can expect the next semester, which directly influences how a student grades his or her timetabling experience. There should also be little time and distance between subsequent lectures. More time between subsequent lectures results in a longer waiting time for students, which often is undesirable. Too much distance between subsequent lectures leads to a longer travel time. This is undesirable according to UU, especially when it is not possible to reach the next location in time. Student satisfaction also includes that a student should be able to compose a study plan in time. This concerns the process of choosing subjects, without too much overlay, before an actual timetable has been made. At last, UU thinks that is important for their students that the range of available education is complete and well-balanced.

The second important aspect in timetabling is the teachers satisfaction. Next to the students, the teachers are also directly affected by the quality of the timetable and the timetabling process. It is important for UU that their employees are satisfied as well. Some of these objective go hand in hand with the student objectives, but teachers have different interests as well. It is important for the teachers that the availability of the rooms is transparent. It should be clear to them which rooms they could possibly use at a given moment. Also the allocation of the rooms should ideally be similar to the request of the teacher. It is very important to certain teachers that they can get certain rooms, so this should be taken into account. Same as for the students, it is important for the teachers that the publication of the timetable is timely and complete and that the publication is

uniform. Changes in the timetable should also be communicated on time. For the teacher it is also important that certain of these changes are discussed with the teacher in question. We concluded from the interviews that teachers like a certain extent of involvement in the timetabling process. It is also important to the teachers that they their scheduled lecture times are in accordance with the communicated availability. At last, teachers at UU often do not like to change the location where they give lectures too often, so the changes of location should be limited.

The third aspect in timetabling objectives that emerged from the interviews, is the organization behind the timetabling process. To provide a qualitative timetable, the process behind this timetabling cannot be pressured to much and the right information should be provided in time. So for the organization it is important that timetable request are timely, realistic and dependable. It is also important that the amount of variables and the amount of process control are manageable.

The fourth aspect is costs. It is important for UU that the costs of education will not become too high. This point is especially emphasized by the board of directors and therefore also in the timetabling objectives. The biggest expense of almost all universities are their buildings, facilities and staff. Since we already discussed staff, the real estate of UU is the main focus when talking about costs. It is important that the available facilities are optimally used. The objective is to strive for the best possible frequency rate, because this means there is a less chance that new buildings are necessary or that UU has to rent other, more expensive, locations. So UU also tries to match the amount of available rooms to the quantitative educational needs. Indirectly related to frequency rate, it is also important that buildings and facilities match the qualitative educational needs. Too many facilities that match a certain educational need may lead to vacancy and not enough facilities may lead to less qualitative education. To do this, it is also important that the room allocation matches the type of education and the amount of students.

4.2 With which KPIs are these objectives measured?

As mentioned in the previous section, UU has four aspects that are important in their timetabling process that each consist of different objectives. These four aspects are: Students, Teachers, Organization and Costs. In this section we have a closer look at these objectives and for each objective we will show how that objective could be measured. This way we create a set of KPIs that measure the timetabling objectives of UU. This is done in collaboration with Miranda van Heesch. It should be noted that these various objectives could be conflicting. In the end should these objectives result in a well-balanced timetable.

STUDENTS

1. *The publication of the timetable is timely and complete:* the final and complete version of the timetable should at the latest be published fourteen days before the start of the course.

2. *The publication of the timetable is uniform:* All final and complete timetables are findable in one system and contain information about time, room and the kind of activity.
3. *Changes in the timetable should be communicated on time*: Changes should be communicated through a channel of communication that is often used by students. A change of the time should be communicated at least 48 hours before the start of the activity in question, a change of location should be communicated at least 24 hours before the start and a cancellation should be communicated 2 hours in advance.
4. *Little time and distance between subsequent lectures:* Subsequent lectures should have as little time, preferably no time, between them. The location of subsequent lectures should be as close as possible.
5. *It should be possible for the students to plan their study:* The annual educational plan with for every course a final period and timeslot should be announced at least one month before the start of the course registration. A student gets a conformation of the applied course within five working days after the expiration of the enrolment.
6. *The range of available education is complete and well-balanced:* The student has to have the possibility to successfully complete the educational plan. There should be enough possibilities for the students to choose and plan their education.

TEACHERS

7. *The availability of the rooms is transparent:* The teacher has an insight in the available rooms and facilities at the moment of the location request.
8. *The allocation of the rooms is in accordance with the request:* The requested and needed facilities are preferably realized in the final version.
9. *The publication of the timetable to the teacher is timely and complete:* The teacher has access to the draft timetable at least six weeks before the publication of the final timetable.
10. *The publication of the timetable is uniform:* The teacher should be able to consult the timetable in one clear system from the moment of publication of the concept timetable till the end of the course.
11. *Changes in the timetable should be communicated on time and discussed with the teacher in question:* If a location request cannot be met, the adjustment should be in coordination with the teacher and the timetabler before the concept timetable is published.
12. *Scheduled times should be in accordance with the communicated availability:* A teacher gives a range of preferred times for his or her course. The time of the course in the final timetable should be one of the communicated times.
13. *Changes of location are limited:* A course should take place at the same location, especially subsequent courses.

ORGANISATION

14. *Timetable requests are timely, realistic and dependable:* All underlying data in the process are final and reliable at the time of the room allocation. The

underlying date consists of the educational programming, the amount of course participants, the list of available rooms and the facilities of the rooms.

15. *The amount of variables and the amount of process control are manageable*: All steps in the process should have added value. Also, the process rules should be used as support and not as an adjustment.

COSTS

16. *The frequency rate of the teaching rooms are as high as possible:* UU aims at an frequency rate of at least 70% at all times that the University is not closed, but a higher frequency rate is always preferable. This also means that facilities are fully used at the times that they are booked and that the amount of participants should be similar to the capacity of the used room.
17. *Buildings and facilities match the qualitative educational needs:* the available rooms are in good technical and well-maintained state. The type of available rooms fits the educational needs and can be flexibly used.
18. *The amount of available rooms should match the quantitative educational needs:* This amount of available rooms facilitates a fitting and high spread of the programmed education across the periods of education.
19. *The room allocation should match the type of education and the amount of students:* the room allocation does not force an unwanted form of education and should not result in a situation where another teacher is needed.
20. *The teachers' room requests match the rooms that are used in reality:* The teacher requests the exact rooms that are need for the course and not a high amount of rooms where he or she can later plan the exact rooms that are needed.

4.3 To what extent is the current set of KPIs from Scientia sufficient?

In the previous section, we discussed which KPIs are of interest to UU. In this section we look at these KPIs and how they relate to the set of KPIs that Scientia offers. We will have a look at which KPIs from UU can be directly linked to one or more of Scientia's KPIs. This way we should also detect if there is a gap between the two sets of KPIs.

The first KPI from UU that can be linked to the KPIs of Scientia is KPI 4 that should measure the amount of time and distance between subsequent lectures or activities for students. First, we need to divide this KPI into two KPIs: one that measures the amount of time between lectures and one that measures the amount of distance between lectures. The amount of time between lectures is directly related to the "grouping of student activities" KPI. This KPI measures the amount of activities in a student's timetable that are being bunched up into a number of tightly packed groups. That also means that it returns a certain value that describes how a timetable scores on the amount of time between subsequent lectures. The amount of distance between lectures cannot directly be linked to an existing KPI that Scientia offers.

The second KPI that can be linked to one of Scientia's KPIs is KPI 6 from UU. A complete and well-balanced range of available education consists of more than one component, so should be split into more than one KPI. Scientia has several KPIs that could measure how complete and well-balanced the timetable is. First of all, there is the "Flexibility of module choice" that measures how many ways there are for a student to complete his or her programme. A higher score means that a student has more options and that the available education is more complete. A well-balanced range of education could be approached by looking at how balanced the student's timetable, that consists of the chosen education, in the end is. Did the students succeed in choosing their courses in a way that their courses are nicely spread across the week? This could be approached by looking at Scientia's KPI: "Spread of student timetable".

The third KPI that can be measured by Scientia's set of KPIs is UU's KPI 16. UU wants to have an as high as possible room frequency rate and wants a KPI that measures this frequency rate. Scientia has the KPI "Frequency of room use" that does this for their Syllabus Plus users. To get a better insight in the use of the different kinds of available rooms, we have to add a new KPI. This possibility will be elaborated later.

The fourth KPI we can, partly, measure with the set of KPIs that Scientia offers, is UU's KPI 18. UU wants the available rooms to fit the requests and wants a timetable that is evenly spread across the week and semester. The first part cannot be directly measured by Scientia's set of KPIs, but we are able to measure the spread across the week and across the year with "Concentration in the week" and "Concentration in the year".

The fifth KPI that we can measure is KPI 19 from UU that should measure how well the room allocation matches the type of education and the amount of students. The type of education cannot be measured currently, but Scientia offers a KPI that measures the difference between a rooms capacity and the amount of students that are allocated to this room: "Space occupancy".

Now that we know the KPIs of UU that can be linked to Scientia's KPIs, we find out that there is a rather large gap between the two sets of KPIs. This is mainly a result of the different way UU and Scientia approach a timetable. UU mainly focusses on the process elements of their timetable, while Scientia is more focused on the measurement of the actual timetable. This does not mean that Scientia does not or is not able to provide this information, but it is currently not included in the set of KPIs that they offer. We continue with a further analysis of the gap in the next section. In Table 1, we summarized the outcomes of this section. The red KPIs are KPIs from UU that cannot be linked to one or more of Scientia's KPIs, the orange KPIs can partly be linked and the green KPIs are already in Scientia's set of KPIs of can be approached by this set.

TABLE 1 COMPARISON OF KPIS UU AND SCIENTIA

KPI	Category	Short description	How can these KPIs be linked to Scientia's set of KPIs?
1	**Students**	Publication is timely and complete	This KPI cannot be linked to a current KPI
2	**Students**	Publication is uniform	This KPI cannot be linked to a current KPI
3	**Students**	Changes communicated on time	This KPI cannot be linked to a current KPI
4	**Students**	Little time and distance between lectures	"Grouping of student activities", but distance between lectures is not included in the current set of KPIs that Scientia offers.
5	**Students**	Possible to plan study	This KPI cannot be linked to a current KPI
6	**Students**	Available education is complete and well-balanced	"Flexibility of module choice" and "spread of student timetable"
7	**Teachers**	Availability of rooms is transparent	This KPI cannot be linked to a current KPI
8	**Teachers**	Allocation of rooms in accordance with request	This KPI cannot be linked to a current KPI
9	**Teachers**	Publication is timely and complete	This KPI cannot be linked to a current KPI
10	**Teachers**	Publication is uniform	This KPI cannot be linked to a current KPI
11	**Teachers**	Changes communicated on time and discussed	This KPI cannot be linked to a current KPI
12	**Teachers**	Scheduled times in accordance with availability	This KPI cannot be linked to a current KPI
13	**Teachers**	Changes of location are limited	This KPI cannot be linked to a current KPI
14	**Organisation**	Requests are timely, realistic and dependable	This KPI cannot be linked to a current KPI
15	**Organisation**	Variables and process control are manageable	This KPI cannot be linked to a current KPI
16	**Costs**	High frequency rate	"Frequency of room use" and possibly a new KPI
17	**Costs**	Facilities match qualitative educational needs	This KPI cannot be linked to a current KPI
18	**Costs**	Amount of available rooms match quantitative needs	"Concentration in the week" & "Concentration in the year" measure the spread of a timetable. Current KPIs does not measure if the allocated rooms fits the request.

19	**Costs**	Room allocation matches education type and amount of students	“Space occupancy” measures a part of this KPI. The match between a room and the type of education cannot yet be measured.
20	**Costs**	Teacher room requests match reality	This KPI cannot be linked to a current KPI

4.4 How should Scientia adapt their set of KPIs to fit a possible gap?

In this paragraph we look at the gap between the desired KPIs from UU and the set of KPIs that Scientia offers. For each KPI or part of KPI from UU that cannot directly be linked to Scientia’s KPIs, we will study the possibilities of including the KPI in Scientia’s set. We show how Scientia should adapt their set of KPIs, by discussing the five KPIs concerning students. We chose students in this section, because UU gave this category the highest priority.

KPI 1

The first KPI that UU would like to see, is a KPI that measures how timely and complete the publication of the timetable is. UU sets the deadline for the publication at fourteen days before the start of a course. At the moment, this goal of fourteen days is not a hard constraint and can be violated. UU would like to see how often this soft constraint of fourteen days currently is met. This question can easily be measured by comparing the “ScheduledDay” and the “WhenScheduled” from the “V_Activity” in the Entity of the Relationship Diagram for each activity as shown in Figure 5.

V_Activity	
PK,FK1	**Id**
FK2	Name HostKey Description TemplateId ActivityTypeId ModuleId DepartmentId SectionId ZoneId SuggestedDays SuggestedStartTime IsScheduled ScheduledDay ScheduledStartTime ScheduledEndTime WhoScheduled WhenScheduled

FIGURE 5 FEASIBILITY STUDENTS 1

The problem is that a scheduled activity is not always complete. Currently the “WhenScheduled” only shows when the first, and possibly incomplete, part of an activity has been scheduled. To get a better insight in the completeness of an activity at a given moment, we have to keep track of specific information of an activity. This means that Scientia should offer a KPI that monitors the times that certain parts of an activity are available. These certain parts can however change per faculty or study. We specify ‘completeness’ as a subset of an activity that has a name, a day, a time, a room and a teacher. Currently the information of the moment that certain parts of an activity are scheduled, is not available in the reporting database of Scientia. There is however another way to measure the completeness of a timetable at a certain moment.

The relational database of Syllabus Plus is a snapshot of the database at the moment that has been chosen by the Syllabus Plus user. Normally each user makes a snapshot at least once a week. In this snapshot, data concerning the

staff, location and time will be available for each activity. It will also be clear if a part of the activity has not been confirmed yet. By looking at each coming activity in fourteen days, we can define a KPI that measures the amount of activities that have a certain stage of completeness. There could for example be a stage of completeness that shows that every aspect of the activity has been defined, except for the teacher that will be responsible for the activity. Every stage of completeness can be defined by the Syllabus Plus users. Some Syllabus Plus users already do this by imprinting each activity with a different stamp that stands for a certain stage of completeness. By doing so, different faculties can also choose to strive for different stages of completeness. They can for example decide that a teacher is not necessary for the activity to be complete. This new KPI should approach the timetable completeness through the whole year. The data for the KPI is available as we can see in the database schema diagram in the appendix. Staff is directly related to the activity as we already described in chapter 2.4. The 'Name, ''ScheduledDay', 'ScheduledStartTime' and 'ScheduledEndTime' are in the 'Activity' table and provide the information for the day, the time and name of the activity. At last the location is also available. The 'V_Location' table is directly connected to the activity with a n to n relation. This means that multiple activities can have the same location and an activity can have multiple locations, as explained in chapter 2.4. A snapshot of the database fourteen days before the start of a semester, will be a good snapshot to run this KPI on.

When the 'completeness' is a part of the activity table, we can build a KPI that measures the completeness of an activity compared to the difference between the expected objects of an activity that needs to be completed (so an activity has a day, a time, a room, student set, a staff member etc.) and the number of objects that are attached to the activity.. A high result means that the expected objects of the activity are filled in, a low result means that e.g. an activity does not have a day, time or a room allocated yet. An activity that takes place in a shorter timespan weighs higher than an activity that does not take place for a while.

KPI 2

The second students' KPI that Utrecht would like to see, is a KPI that measures how findable the timetable is for students and how complete this timetable is. The availability of the timetable is a KPI that focusses on the service-end of timetabling and is not something that can be measured by data that Scientia offers. UU could count the places where the timetable can be found and built a KPI around that, but cannot be measured with timetable data. The part of how complete the timetable is, is the same as before, because it is more urgent to have an activity complete when it takes place in a few weeks than in a few months..

KPI 3

UU also would like a KPI that measures if changes are communicated on time and that this is communicated through one clear channel. The workflow of communication cannot be measured with timetable data, but we can measure how timely the communicated change was. We define 'how timely' as the difference between a certain change in the activity and the planned time of that activity. The data that is needed for those two variables is available. As shown in Figure 6, 'lastChanged' keeps a record of when there last was a change for each activity. This can be used to see if there have been changes close to when the activity takes or took place. 'LastChanged' in 'V_Activity' does not keep a record of what has been changed in the table. The day and time of an activity is also available, as we discussed in a previous section.

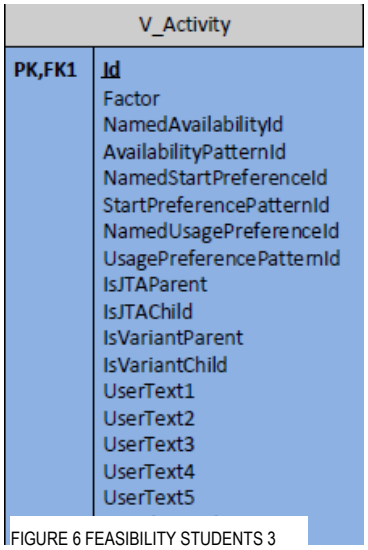

FIGURE 6 FEASIBILITY STUDENTS 3

UU indicated that a change of time should be communicated at least 48 hours before the start of the activity, a change of location at least 24 hours and a cancellation should be communicated at least 2 hours in advance. For the KPI to take into account when the time and location last were changed as well, the variables 'LastChangedTime' and 'LastChangedLocation' need to be introduced to the 'V_Activity' table. The current 'LastChanged' in 'V_Location' cannot replace this 'LastChangedLocation' in the activity table, because it does not contain information about the location of each activity. Instead it contains information about when a change in the location itself has been made. To compare the time of cancellation with the planned time of the activity we should add a 'cancelled' table, related to 'V_Activity', that contains information about the time of cancellation if the activity was cancelled.

The new KPI measures for each activity the moments of a change of time, change of location or the time of cancellation and the planned time of the activity, compared to the communicated times that UU strives to get. A high number as result means a high amount of activities that have been changed in time.

KPI 4

To measure how far different locations are from each other, we need to know where each location is located. The precise location is currently not available, but each location can be linked to a predetermined zone. The zones are specified by the university. A zone could for example mean a building or a group of buildings. We make the assumption that zones are specific enough to give a sufficient estimation of the travel time. As shown in Figure 5, each activity has this "ZoneID". It is essential that UU links each location to a certain zone in Syllabus Plus. When this has been done, it is possible to see when students need to change zones between subsequent lectures. Based on the times of different activities and the

student that is related to the activity, we can deduce if it is a subsequent lecture for the student in question.

Based on these available variables, we can build a KPI that measures the time to travel between two locations of two activities on the same day compared to the time between those activities. A high number as result means a short time to travel compared to a long time between the activities. A low number indicates a long time to travel compared to a short time between the two activities. Note that the time to travel should be lower than the time between activities. This should therefore be a hard constraint.

KPI 5

The fifth KPI for students focusses on the process that takes place before making the actual timetable. A student should be able to plan his or her study. This means that every course should be published on time, a student gets a conformation in time, etc. As this process is not part of the actual timetabling process, this KPI should be addressed in a different study.

In this chapter we found that the timetabling of UU can be categorized into four segments: students, teachers, organisation and costs. We also found timetabling KPIs within these categories. These KPIs were compared to Scientia's existing set of KPIs and a gap between these sets was found. For the category of students, we studied how this gap could be filled and found three KPIs that can be added to Scientia's set of KPIs.

5 CONCLUSION

At the start of this research the question was asked: W*hich set of timetable KPIs does Scientia need to offer to fit the objectives of Utrecht University*? This question was approached by answering four sub-questions:

1. *What are the timetabling objectives of Utrecht University?*
2. *With which KPIs are these objectives measured?*
3. *To what extent is the current set of KPIs from Scientia sufficient?*
4. *How should Scientia adapt their set of KPIs to fit a possible gap?*

We concluded in sub-question 1 that UU has four categories of timetabling objectives: *Students, Teachers, Organisation* and *Costs.* In those categories there are several objectives, which were measured with the KPIs that were studied in the second sub-question. These KPIs of UU were compared to the current set of KPIs that Scientia offers. We summarised the twenty KPIs in Table 1 in chapter 4. We concluded that, in total, there are fifteen of UU's KPIs missing in Scientia's current list of KPIs, three KPIs can partly be linked to Scientia's KPIs and two KPIs can directly be linked. We concluded in sub-question three that there is a gap of eighteen KPIs that are missing or partially missing.

As we restricted the fourth sub-question to KPIs concerning students, the KPIs concerning teachers, organisation and costs will be excluded in the answer of the main research question. Having said that, we propose to add three new KPIs to the current set of KPIs that Scientia already offers:

1. *Completeness of the timetable*: a KPI that measures the completeness of all activities in the timetable database. Based on this completeness and the time till the start of the activity, this KPI can measure how complete a timetable is at a given moment. The 'completeness' can differ between courses and faculties. No additional data is needed.
2. *Communication of timetabling changes*: this KPI measures the time between the communication of a change in the timetable and the planned time of the activity in question. Ideally, we would make a distinction between a change in time, a change in location or a cancellation, but additional variables are needed in the database.
3. *Travel time*: With this KPI, we measure the travel time between subsequent activities and return a value based on the length of this travel time and the time between the activities. No additional data is needed, but the user of Syllabus Plus should define zones and connect those to locations.

We recommend Scientia to incorporate these KPIs in the set of KPIs that they offer and to conduct further research about the other missing KPIs. The developed comparison in this research can most likely be extended to other institutes of higher education. This research can be used in the acquisition of future customers by showing this customer oriented approach of Scientia.

6 DISCUSSION

In this chapter we discuss further research, improvements of this research and the limitations of this research.

First of all, we would like to state that this research is a case study at UU. We mentioned in chapter 3 that there are downsides with a case study. The results of the case study at Utrecht University need additional research to be able to generalize the results with a higher certainty of success.

Secondly, only the missing KPIs concerning students were worked out. Additional research is needed to study the possibilities of adding new KPIs concerning teachers, organisation and costs.

Thirdly, we think that more feedback moments were necessary in this research. Were the findings of the interviews correct and did this research fit the objectives of UU?

As fourth, we think that more education of timetabling objectives and KPIs to UU would have made a difference in their choices. Knowledges about the possibilities of KPIs might influence the requested timetabling objectives.

APPENDIX

6.1 Database Schema Diagram

Not available

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