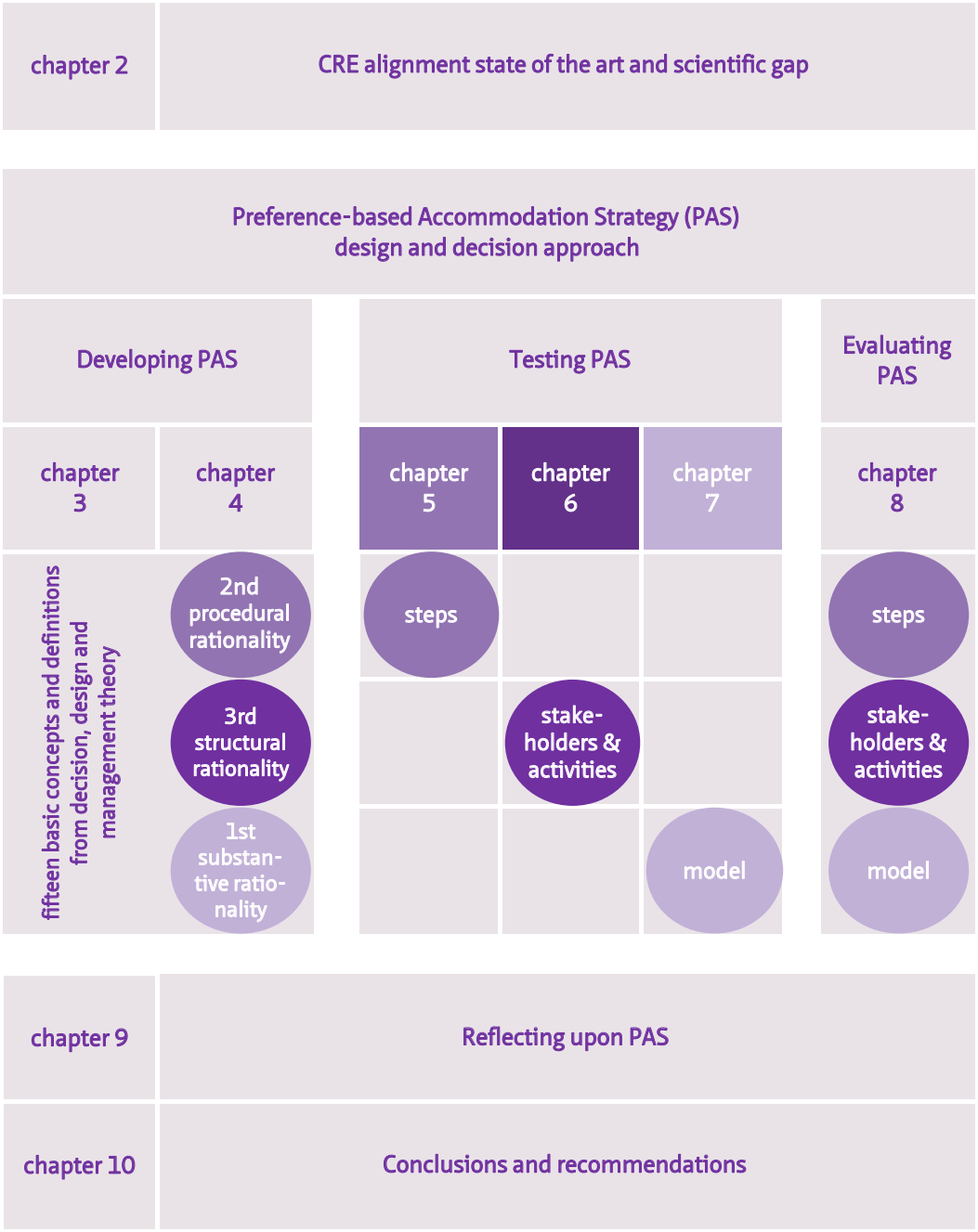
5 PAS steps to achieve alignment


chapter 2
CRE alignment state of the art and scientific gap
Preference-based Accommodation Strategy (PAS)
design and decision approach
Developing PAS
Testing PAS
Evaluating PAS
chapter 3
chapter 4
chapter 5
chapter 6
chapter 7
chapter 8
fifteen basic concepts and definitions from decision, design and management theory
2nd procedural rationality
3rd structural rationality
1st substan-tive ratio-nality
steps
stake-holders & activities
model
steps
stake-holders & activities
model
chapter 9
Reflecting upon PAS
chapter 10
Conclusions and recommendations

TOC

5 PAS steps to achieve alignment

The focus in this chapter is on the component steps of PAS (see **Figure 5.1** and **Figure 5.2**). CRE alignment is achieved, as has been shown in chapter 4, if stakeholders can use PAS successfully. PAS is successful if the stakeholders are able to perform each step of PAS. I assume that the stakeholders can perform steps 1 (specifying decision variables), 3 (assigning weights) and 4 (determining design constraints) because these type of steps are part of other multi criteria decision analysis as well. However, it is not known if stakeholders are able to perform the new step 2 (determining preferences) and step 5a (design alternatives) and are willing to select the alternative with the highest overall preference score in step 6. Preferably, this new alternative has a higher overall preference score than the overall preference score in the current situation. However, if the boundary conditions are strict this is not always possible. PAS has been tested in three pilots.

This chapter has the following structure:

- TU Delft pilot for the food facilities in paragraph 5.1;
- TU Delft pilot for lecture halls in paragraph 5.2;
- Oracle's pilot for office locations in paragraph 5.3;
- Pilot study comparison and conclusion in paragraph 5.4.

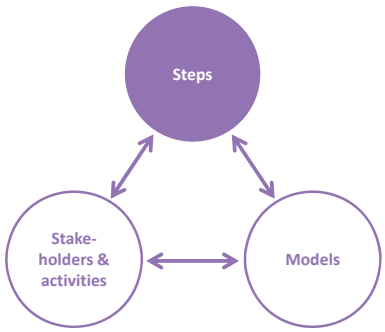


FIG. 5.1 Focus in this chapter
Note adapted from Arkesteijn et al., 2017, p. 245

TOC

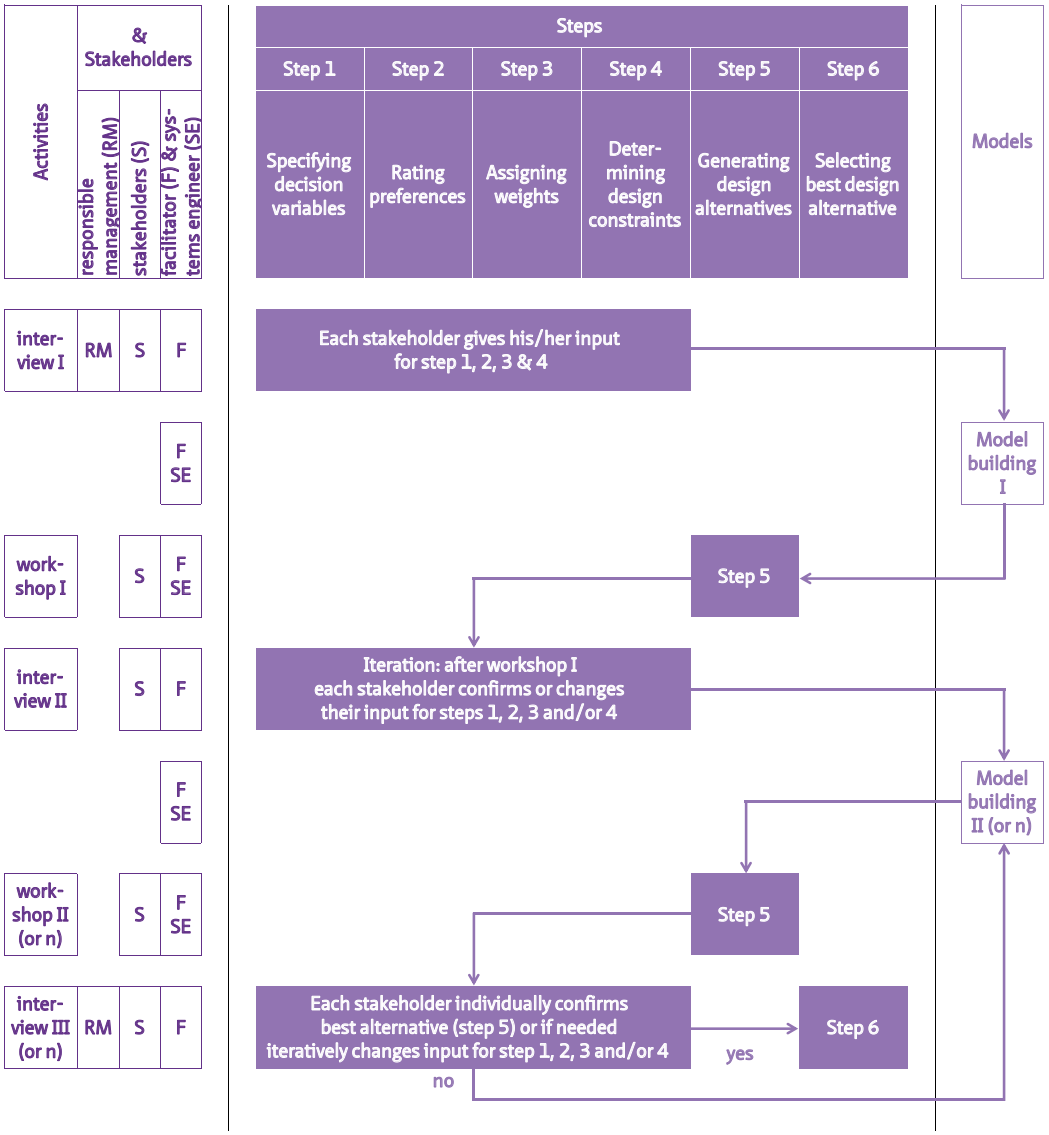


FIG. 5.2 PAS Flowchart; emphasis on steps Note adapted from Arkesteijn et al., 2017, p. 248

TOC

5.1 Pilot study 1: TU Delft's food facilities

The results of this pilot study have been published in 2017 in the Journal of Corporate Real Estate. This means that part of the text of the paragraph is reproduced. In this chapter, paragraphs 5.1.1 and 5.1.2 are more elaborate than in the paper or than in pilot 2 and 3 to show how the stakeholders have defined their first set of decision variables[38]. The pilot study starts with an introduction of the pilot (paragraph 5.1.1), followed by each of the PAS steps.

5.1.1 Introducing the pilot study

TU Delft is located in the city of Delft, between the cities of Rotterdam and The Hague in The Netherlands. At that time [2012], the university accommodated 18,800 students and 7,600 employees (including 1,600 guests). In terms of land and buildings, TU Delft is the second largest university in The Netherlands: its building portfolio consisted of 570,000 m2 gross floor area. In addition, the university owns approximately 170 hectares of land. All university buildings are located on a campus south of the city center, between a Canal (the Schie) and a highway (A13). The campus consists of three areas – TUD North, TUD Central and TUD South – each with a unique character. (Arkesteijn et al., 2017, p. 249). (see **Figure 5.3**)

More than 75% of the total surface area of the university buildings is located in TU Central, the area designated for education and research. TU South is designated for companies affiliated with the university's research activities. TU North accommodates the Architecture Faculty, residential facilities, recreational facilities and small enterprises, owing to the area's close proximity to the city center and architectural features of the buildings, which date from the early 20th century.

A substantial part of its portfolio was built in the 1960s and 1970s and will require largescale renovation in the near future. The university has defined a new campus vision – "the living campus" – and made plans to renovate parts of the campus, to reduce the size of its portfolio and to lower its accommodation costs. The university's facility and real estate department (FMRE) has expressed the desire

38 The cited text is displayed in purple. Only in the first two subparagraphs the parts from the paper will be quoted. Next, to that the figure and table numbers are adjusted to fit in this thesis.

to develop these plans together with the various stakeholders on the campus, to determine which improvements are necessary and where space can be used more effectively and efficiently.

The food facilities on campus (i.e. facilities that serve coffee, lunch and/or dinner) are a critical asset when it comes to realizing a living campus. The ambition of the living campus is to maximize the function of the campus as a place to meet each other and work together. Therefore an important condition for the living campus is to have high-quality food facilities located at strategic locations. The current facilities of TU Delft (**Figure 5.3**) do not meet the requirements of students and staff – especially amongst international users – according to various surveys. The exact requirements of the users are not clear, however: Are the facilities at the wrong locations? Are there not enough facilities that serve coffee, or too many facilities that serve dinner? (Arkesteijn et al., 2017, p. 249). In other words, the CRE portfolio is not aligned with the organization.

The university's campus has fourteen food facilities, which serve coffee, lunch and/or dinner (see **Figure 5.3**). The fourteen food facilities in total have 2.268 places in an area of 3.491 gross floor area (see **Table 5.1**). Most facilities are in ownership of DUT except for the sports center and Inholland. However, because there are located on or adjacent to the campus students and staff are able to use them. Therefore we have taken them into account in this project. As can be seen in the table, two faculty buildings (ARCH and CEG) have two food facilities. In **Figure 5.4** and **Figure 5.5** an impression is given of the food facilities.

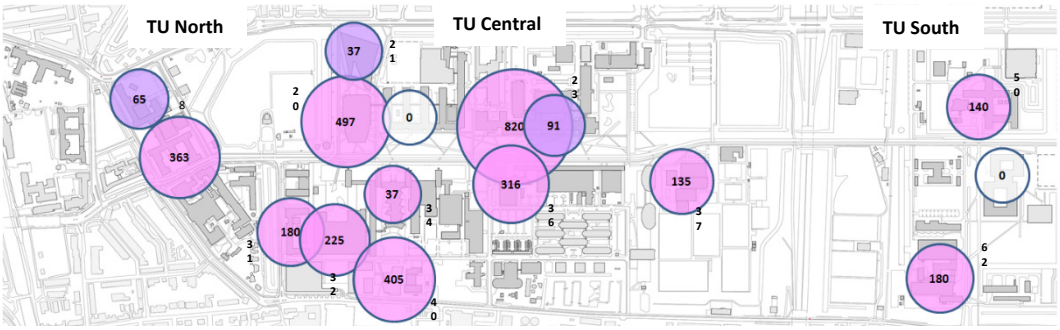


FIG. 5.3 Three areas on the TU Delft's campus Note adapted from Arkesteijn et al., 2017, p. 250 Legend: purple circles: coffee corner, pink circle restaurant; number in circle g.f.a and size of circle corresponding to size of facility. Building numbers added in squares corresponding to **Table 5.1**.

TOC

TABLE 5.1 Overview of food facilities and basic data (ordered on building number)

Faculty	Building number	Type of food facility	Gross floor area	# places (i.e. seats)	TUD ownership
Architecture and the built environment (ARCH)	8	restaurant for lunch & diner with coffee corner	363	210	yes
	8	coffee corner	65	60	yes
Auditorium	20	restaurant for lunch & diner with coffee corner	497	267	yes
Library	21	coffee corner	37	32	yes
Civil engineering and Geosciences (CEG)	23	restaurant for lunch	820	450	yes
	23	coffee corner	91	10	yes
Technology, Policy and Management (TPM)	31	restaurant for lunch	180	120	yes
Industrial design Engineering (IDE)	32	restaurant for lunch with coffee corner	225	250	yes
Mechanical, Martime, Materials Engineering (3ME)	34	restaurant for lunch with coffee corner	37	32	yes
Electrical Engineering, mathematics, Computer Science (EEMCS)	36	restaurant for lunch with coffee corner	316	267	yes
Sports Centre	37	restaurant for lunch with coffee corner	135	90	no
Inholland	40	restaurant for lunch & diner with coffee corner	405	270	no
Reactor	50	restaurant for lunch	140	50	yes
Aerospace engineering (AE)	62	restaurant for lunch	180	160	yes
Total			3.491	2.268	

Many of these food facilities cause dissatisfaction with the university's students and staff. The food facilities are aged and need to be renovated. Representatives from FMRE claim that there is insufficient capacity and quality in the food facilities and insufficient room for commercial food facilities.

The pilot study focuses on the question of how to maximize the function of the living campus by designing a strategy for the university's food facilities. The strategy looks to optimize the amount of food facilities on campus, the types of food facilities and their locations within the campus and buildings based on the specific requirements formulated by users. Which portfolio of food facilities will enable TU Delft to reach her objectives best? The types of questions that need to be answered are: How many food facilities and which types are needed? Where are the food facilities located? What is their preferred size? (Arkesteijn et al., 2017, p. 251).

Building 23, Faculty CEG, restaurant

Building 23, Faculty CEG, coffee corner

Building 31, Faculty TPM, room C

Building 32, Faculty IDE, restaurant

Building 37 Sports Centre, restaurant

Building 40, Inholland, restaurant

FIG. 5.4 Photos food facilities continued Note photos by Arkesteijn & Valks

Building 8, ARCH, restaurant

Building 8, ARCH, coffee corner

Building 20, Auditorium, restaurant

Building 36, EEMCS, restaurant

FIG. 5.5 Photos food facilities continued Note photos by Arkesteijn & Valks

5.1.2 Stakeholders specified decision variables (step 1)

"At the outset of the project, an executive board member was appointed as responsible management who, together with the real estate manager, determined which stakeholders were to participate in the pilot" (Arkesteijn et al.,2017, p. 252). **Figure 5.6** displays the stakeholders that participated in the pilot and the final decision variables they have specified. The executive board as responsible management for real estate projects, the faculty secretary as representative of the faculties, the student council as representative of the students, the works council as representatives of the employees and the project leader social innovation. The latter represents a special university program on social innovation. "Some groups were represented by multiple participants (e.g. the members of the works council), whilst others consisted of only one participant (e.g. the faculty secretary)" (Arkesteijn et al.,2017, p. 252).

decision makers		decision variables
student council	1	Maximum walking time from a faculty building to a food facility for lunch [minutes]
	2	Maximum walking time from a faculty building to a food facility for dinner [minutes]
	3	Percentage of places in all food facilities which can be used for working [%]
	4	Average vertical location of food facility [floors]
	5	Amount of doors between outside and the food facility [doors]
	6	Average walking time from an entrance to a food facility [minutes]
faculty secretary	7	Maximum walking time from a faculty building to a food facility for lunch [minutes]
	8	Maximum walking time from a faculty building to a food facility for dinner [minutes]
	9	Percentage of places in all food facilities which can be used for working [%]
	10	Percentage of places in the facilities having sufficient acoustics [%]
	11	Average preference rating on ambience for the food facilities [-]
works council	12	Maximum walking time from a faculty building to a food facility for lunch [minutes]
	13	Maximum walking time from a faculty building to a food facility for dinner [minutes]
	14	Percentage of food facilities labelled diverse [%]
	15	Average preference rating on coziness for the food facilities [-]
pl social innovation	16	Percentage of places in all food facilities which can be used for working [%]
	17	Average preference rating on find-ability of the food facilities [-]

FIG. 5.6 Decision makers and their variables Note adapted from Arkesteijn et al., 2017, p. 252

Recall, that in chapter 3, stakeholders in PAS are defined as designers and decision makers; all terms are used interchangeably to refer to them. Before the stakeholders were able to specify the decision variables as shown in **Figure 5.6** each stakeholder was interviewed in order to understand their problems and objectives better and translate these objectives into criteria which are important for their group. For each stakeholder group this process will be shown below.

Student council

The student council indicates in the interviews that students experience three main *problems* with the food facilities (see **Figure 5.7**[39]). Firstly, they are dissatisfied with the accessibility of the facilities. Secondly students want to be able to work[40] in the

39 In the paper the variables have been numbered (Figure 5.4). During the pilot study the variables were organized differently (Figure 5.7). The variables are not in numerical order but the numbers have been added.

40 In this thesis, places to work for students are referred to as work places. In other research, these place can be referred to as study places.

food facilities which currently is not possible. There are only some places in the food facilities which can be used as work places. And last but not least the quality of the facilities needs to be improved. The price quality ratio of the restaurants, especially for the luxury sandwiches and the hot meals, is not good, according to the students.

problems	objectives	variables
Accessibility is not good	Quick accessibility	Maximum walking time from a faculty building to a food facility for lunch [minutes] (variable 1)
		Maximum walking time from a faculty building to a food facility for dinner [minutes] (variable 2)
		Average vertical location of food facility [floors] (variable 4)
		Amount of doors between outside and the food facility [doors] (variable 5)
		Average walking time from an entrance to a food facility [minutes] (variable 6)
Can not work in food facilities	Work places in the food facilities	Percentage of places in all food facilities which can be used for working [%] (variable 3)
Price quality ratio is not good	Good price quality ratio	Variable to be used in a later stage of decision making

FIG. 5.7 Summary of problems, objectives and decision variables student council

The students state three *objectives.* They want (1) quick access to the food facilities, (2) study places in the food facilities and (3) a good price quality ratio in the facilities. These objectives are subsequently translated into variables .

The objective *quick accessibility* is translated into different decision variables. Sometimes there is no food facility in the building where students are working. In that case, they have to go to another building. Students indicate that this is only acceptable within certain time limits. They make a distinction between accessibility of a restaurant for lunch and a restaurant for dinner. Lunch facilities need to be much closer to them than the dinner facilities. The *first* variable therefore is the maximum walking time from a faculty building to a food facility for lunch. They ideally want to walk one minute, while three minutes is already too far for them. The *next* variable, number *two*, is the maximum walking time from a faculty building to a food facility for dinner. For dinner students are prepared to walk longer, ideally they walk four minutes or less, while that ten minutes walking is too long. The *next* variable (referred to as number *four*) is about the location of the food facilities. Ideally, they are located on the ground floor while two floors is unacceptable. The variable

is named the average vertical location of food facility. A quick access to the food facilities means they, ideally, want to pass only one door when entering the building before they reach the food facility. The *fifth* variable therefore is the amount of doors between outside and the food facility' The next variable, number *six*, is the average walking time from an entrance to a food facility, which should be ideally only halve a minute. If they have to walk three minutes or more they find this too far.

The next objective students have is that they want work places in the food facilities. For this, the students define their *third* variable the 'percentage of places in all food facilities which can be used for working'. A place is usable as work place only if there is wifi (enough bandwidth) and one socket per place. At the same time, students want the real estate department to indicate clearly at which times these place can be used as work place and when they are solely usable for people eating in the restaurant.

Faculty secretary

In the interviews, the faculty secretary indicates several *problems and objectives* with the food facilities (see **Figure 5.8**). The first *problem* for the faculty secretary is that they want to be able to do other activities in the food facilities as well. The food facilities have peak hours during lunch and are less busy in the other hours. The faculty secretary wants to use the food facility in these hours for other activities, like working alone or in groups or maybe even for conferencing. These activities currently cannot be performed in the facilities. The second problem is that they do not like the atmosphere in some of the facilities. Some facilities look outdated. Thirdly, they indicate that the assortment is too much oriented at the Dutch kitchen. Fourthly, there is too much odor, due to staff and students using micro waves to heat their own brought food. This problem is actually a result of problem three , as the microwave is mostly used by international students. And lastly, the hygiene of the restaurant places could be improved. The tables and chairs should be cleaner.

The faculty secretary states four *objectives.* They want (1) multi-functional use of the restaurant places, (2) a more divers offer of food facilities, (3)wider opening hours for the food facilities; since the faculties are open longer as well and (4) a food market with different small food providers. These objectives are mostly translated into variables.

'Walking distances' is an important variable for the faculty secretary, although this was not identified as a problem or objective in the first interview. They use the same variables as the students' variables *one* and *two*. The only difference is that the faculty secretary has different demands for the walking times. Variable *seven* is

'maximum walking time from a faculty building to a food facility for lunch'. Ideally, they want to walk three minutes, while nine minutes is too far. Variable *eight* is the 'maximum walking time from a faculty building to a food facility for dinner'. For dinner, the faculty secretary is prepared to walk longer, ideally six minutes or less, while eighteen minutes walking is too long.

problems	objectives	variables
No problem defined	No objective defined	Maximum walking time from a faculty building to a food facility for lunch [minutes] (variable 7)
		Maximum walking time from a faculty building to a food facility for dinner [minutes] (variable 8)
One-functional use of restaurant places	Multi-functional use of the restaurant places	Percentage of places in all food facilities which can be used for working [%] (variable 9)
		Percentage of places in the facilities having sufficient acoustics [%] (variable 10)
	Wider opening hours	No variable defined
Frigid or outdated atmosphere	A more divers offer of the food facilities	Average preference rating on ambience in all food facilities (-) (variable 11)
Dutch oriented kitchen		No variable defined
	A food market	No variable defined
Too much odour	No objective defined	No variable defined
Insufficient hygiene	No objective defined	No variable defined

FIG. 5.8 Summary of problems, objectives and variables faculty secretary

The first objective is to have multi-functional places in the food facilities. In order to make the places available for working, the faculty secretary states the 'percentage of places in all food facilities which can be used for working' as variable *nine*. This is the same as variable *three* from the students. At the same time, the faculty secretary wants people to be able work in groups of four to eight people in the restaurant. Therefore, it is necessary to have some kind of semi-enclosed compartments in the restaurants, in combination with sufficient acoustics. Presently, most restaurants are one big open plan area with many disturbances. They formulate variable *ten* as the 'percentage of places in the facilities having sufficient acoustics'.

A more diverse offer of the food facilities, is the faculty secretary's second objective. The faculty secretary specifies a variable about the ambience in the food facilities,

although they did not specifically set an objective regarding this variable. Ambience is related to the problem of outdated facilities. In order to understand which ambience the faculty secretary likes or dislikes, they were asked to rate all the current facilities on preference for ambience. Variable *eleven* is 'average preference rating on ambience in all food facilities'.

The faculty secretary does not give any variables for 'wider opening hours for the food facilities since the faculties are open longer as well' and 'a food market with different small food providers'.

Works council

The works council represents the employees. In their interviews, they state that they experience several problems with the food facilities (see **Figure 5.9**). Firstly, the accessibility of the facilities is not good. The food facilities are far away for some faculty buildings. Secondly, the employees indicate that some food facilities are very busy, especially during peak hours. The capacity is insufficient. This is true for some food facilities, partially due to the closing of a food facility which causes pressure at another food facility. They also indicate that the capacity is even lower during events like conferences, which causes problems for employees and students. However, there are not many conferences in faculty buildings. Some have conferences twice a year. Thirdly, the employees indicate that the food facilities are not diverse. The uniformity is seen in the table sizes. Mostly all tables in a food facility have eight or ten places. Last but not least they indicate that the prices are too high.

problems	objectives	variables
Accessibility food facilities not good enough	Each building should have a lunch facility	Maximum walking time from a faculty building to a food facility for lunch [minutes] (variable 12)
		Maximum walking time from a faculty building to a food facility for dinner [minutes] (variable 13)
Not enough capacity	Food facilities close only very sparsely	No variable defined
Not diverse enough	Diversity and cosiness in the food facilities	Percentage of food facilities labelled diverse [%] (variable 14)
		Average preference rating on cosiness for all food facilities [-] (variable 15)
Price is too high	No objective defined	No variable defined

FIG. 5.9 Summary of problems, objectives and variables for the works council

The employees state three objectives. Firstly, *t*hey want that each building has a lunch facility where employees can meet each other during the lunch. Secondly, they want diversity and coziness in the food facilities. And last, they want that the food facilities close only very rarely. These objectives are subsequently translated into variables.

The objective to have a food facility in each building is translated into the two variables accessibility of a restaurant for lunch and a restaurant for dinner. If the walking time is short, this means the food facility needs to be in each faculty building. These are the same variables as variables one and two as indicated by students and faculty secretary. Variable *one* is the 'maximum walking time from a faculty building to a food facility for lunch'. They ideally want to walk two minutes or less to such a facility, while five minutes is too far for them. Variable *two* is the 'maximum walking distance from a faculty to a food facility for dinner'. For dinner employees are prepared to walk longer, ideally they walk three minutes or less, while eight minutes walking is too long.

The objective to have diversity and coziness in the food facilities is translated into the two variables by the employees. The first is variable *ten,* the 'percentage of food facilities labelled diverse'. For each food facility the amount of places per table is counted. The counts shows how many tables for four persons, five, six etc. persons are available in the facility. If, based on the count, it shows that there are many different table sizes the facility is indicated as diverse. If, on the other hand, the table sizes are uniform, the facility is indicated as not diverse. The following variable for the employees is coziness which is based on preference, just like the variable six regarding ambience of the faculty secretary. In order to understand which facilities the employees find cozy or not, they were asked to rate all the current facilities on preference for coziness. Variable *eleven* therefore, is 'average preference rating on coziness for all food facilities'. The works council did not set a variable for the capacity of places.

Project leader Social Innovation

The project leader social innovation indicates in his interviews that he experiences no *problems* with the food facilities (see **Figure 5.10**). He states two *objectives*. The restaurant should serve as a space to meet people and he wants the users to be satisfied.

These objectives are translated by the project leader into two variables. Variable *sixteen* is ability to work in the food facilities . This is the same variable as variable *three* of the students and variable *nine* of the faculty secretary. Variable *seventeen* is that the food facility can be easily found. This variable does not have a unit and the preference is given directly, just like variable *eleven* and *fifteen*. He indicates that the facility is easy to find when it is located next to the main entrance. It is still easy to find if it is on the main (traffic) artery. It is, however, less findable than next to the main entrance. The project leader indicates it is not easy to find a restaurant if it is located elsewhere in the building. This is variable *seventeen* 'average preference rating on findability of the food facilities'.

problems	objectives	decision variables
No problems defined	Spaces for meeting each other	Percentage of places in all food facilities which can be used for working [%] (variable 16)
		Average preference rating on findability of the food facilities [-] (variable 17)
No problems defined	User satisfaction	No variable defined since the users have defined their own variables in this pilot project.

FIG. 5.10 Summary of problems, objectives and variables for the project leader social innovation

unique number	decision variables	number decision variables stakeholders			
U1	Maximum walking time from a faculty building to a food facility for lunch [minutes]	1	7	12	
U2	Maximum walking time from a faculty building to a food facility for dinner [minutes]	2	8	13	
U3	Percentage of places in all food facilities which can be used for working [%]	3	9		16
U4	Average vertical location of food facility [floors]	4			
U5	Amount of doors between outside and the food facility [doors]	5			
U6	Average walking time from an entrance to a food facility [minutes]	6			
U7	Percentage of places in the facilities having sufficient acoustics [%]		10		
U8	Average preference rating on ambience for the food facilities [-]		11		
U9	Percentage of food facilities labelled diverse [%]			14	
U10	Average preference rating on coziness for the food facilities [-]			15	
U11	Average preference rating on findability of the food facilities [-]				17

FIG. 5.11 Comparison of unique variables (U1 to U11) to numbered variables (1 to 17)

TOC

Results step 1: specifying the decision variables

The decision makers specified seventeen decision variables (**Figure 5.11**). There are three variables which are of interest to four different decision makers: walking time to the middle-sized (variable 1, 7 and 12) and large-sized food facilities (variable 2, 8 and 13) and the number of places in the restaurant which can be used for working (variable 3, 9 and 12). Apart from these variables, which are quantitatively oriented, the decision makers also use qualitatively oriented variables such as ambiance (variable 11) and coziness (variable 15). (Arkesteijn et al., 2017, p. 251).

5.1.3 Stakeholders determined preferences (step 2)[41]

For each variable, the decision makers determined a bottom reference alternative (x_0, y_0), a top reference alternative (x_1, y_1) and an intermediate reference alternative (x_2, y_2). For example, **Figure 5.12** displays preference ratings of the participant faculty secretary to the variable 'food facility place as work place.' The bottom reference (preference score 0) alternative (x_0, y_0) is set at 0 percent, the top reference (preference score 100) alternative (x_1, y_1) is set at 50 percent and the intermediate reference (preference score 80) alternative (x_2, y_2) at 40 percent.

During the pilot, the stakeholders have seen the curves they have defined as presented in **Figure 5.13** (works council), **Figure 5.14** (student council)[42], **Figure 5.15** (faculty secretary) and **Figure 5.16** (project leader social innovation). This gave them visual feedback about their preferences. The preference ratings as coordinates are displayed in **Figure 5.17**.[43]

41 From here the results of the pilot study are shown as presented in paragraph 6.1.2 to 6.1.6 Arkesteijn et al.,2017, pp. 252-257). The cited text is displayed in purple, added text in black. Paragraph, figure and table numbers have been adjusted. In the JCRE paper, the preference curves have only been presented in a table, in this thesis they are also presented as graph. Minor language changes have been made. Colors are synchronized in print version.

42 In chapter 4, it has been explained that curve fitting has one disadvantage and that is that it can lead to preference scores above 100 or below 0. This was the case for # doors (variable 5) (in top right corner of Figure 5.14) and in Figure 5.16 % work places (variable 16; also top right corner). The order in which the curves are presented are similar as in the model, which is not the same order as in Figure 5 17.

43 For the variables without a unit (see variable coziness Figure 5.13, ambience Figure 5.15 and findability Figure 5.16) the preference curve determines the relationship between the average preference score for the total portfolio, i.e. all appropriate objects, to a preference score. The stakeholders have given a preference rating for each of the current facilities (see appendix D).

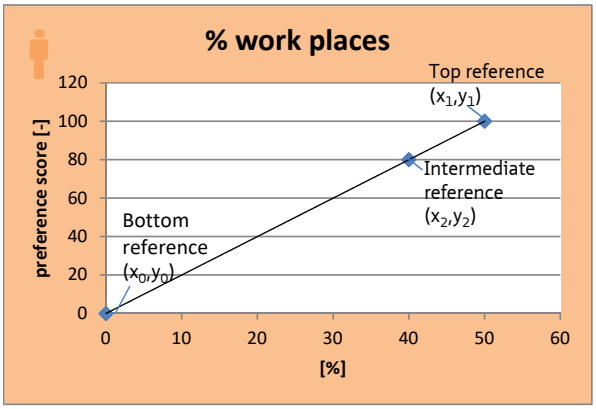


FIG. 5.12 Lagrange curve for the variable "ability to work in the food facility" (see also in Figure 5.17, variable 9); the curve represents the demand and relates the preference rating (vertical axis) to variable value (on the horizontal axis) Note adapted from Arkesteijn et al., 2017, p. 253

FIG. 5.13 Preference curves works council

TOC

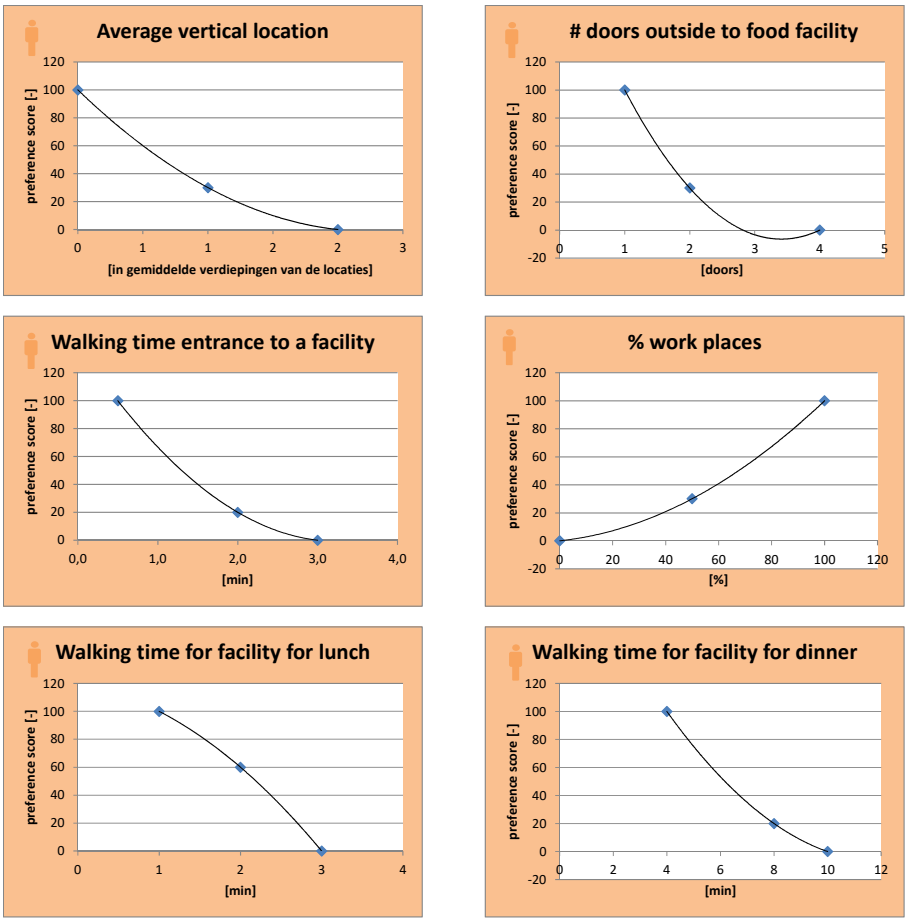


FIG. 5.14 Preference curves student council

TOC

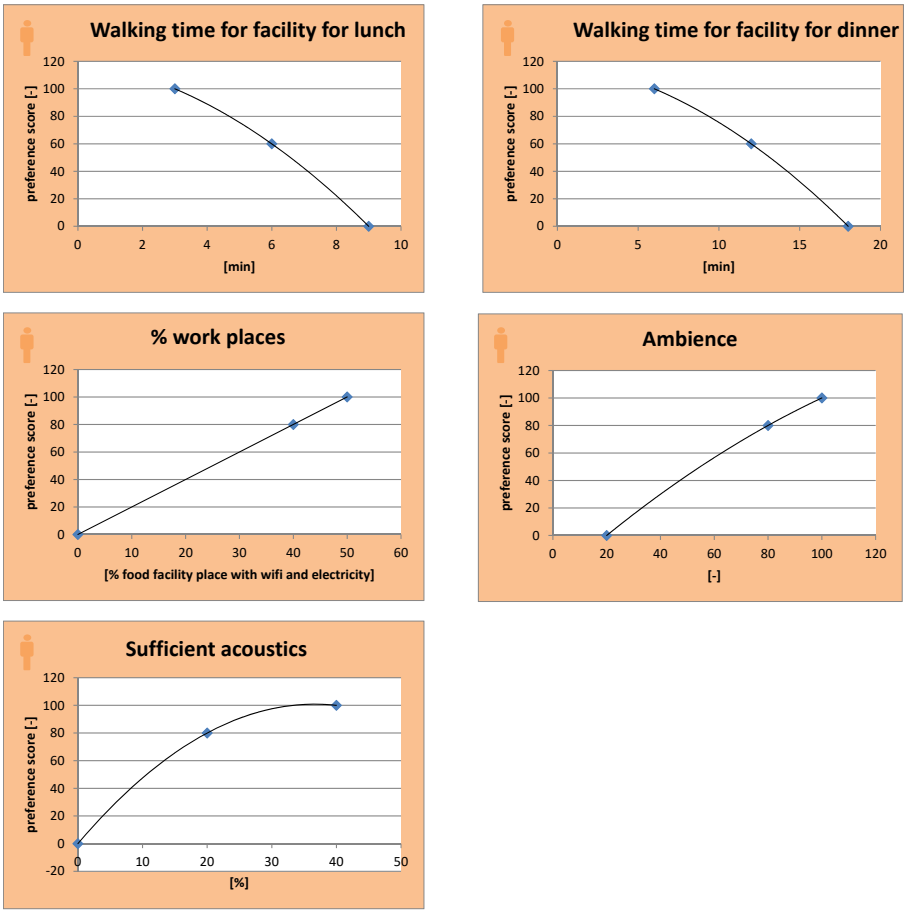


FIG. 5.15 Preference curves faculty secretary

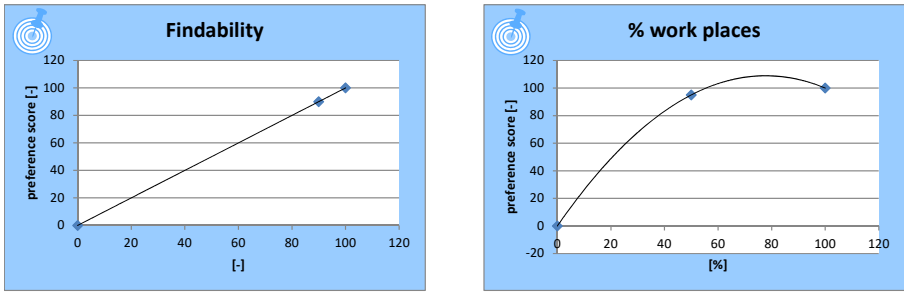


FIG. 5.16 Preference curves project leader social innovation

TOC

decision makers		decision variables	$[x_0, y_0]$	$[x_1, y_1]$	$[x_2, y_2]$
student council	1	Maximum walking time from a faculty building to a food facility for lunch [minutes]	[3, 0]	[1, 100]	[2, 60]
	2	Maximum walking time from a faculty building to a food facility for dinner [minutes]	[10, 0]	[4, 100]	[8, 20]
	3	Percentage of places in all food facilities which can be used for working [%]	[0, 0]	[100, 100]	[50, 30]
	4	Average vertical location of food facility [floors]	[2, 0]	[0, 100]	1, 30]
	5	Amount of doors between outside and the food facility [doors]	[4, 0]	[1, 100]	[2, 30]
	6	Average walking time from an entrance to a food facility [minutes]	[3, 0]	[1, 100]	[2, 20]
faculty secretary	7	Maximum walking time from a faculty building to a food facility for lunch [minutes]	[9, 0]	[3, 100]	[6, 60]
	8	Maximum walking time from a faculty building to a food facility for dinner [minutes]	[18, 0]	[6, 100]	[12, 60]
	9	Percentage of places in all food facilities which can be used for working [%]	[0, 0]	[50, 100]	[40, 80]
	10	Percentage of places in the facilities having sufficient acoustics [%]	[0, 0]	[40, 100]	[20, 80]
	11	Average preference rating on ambience for the food facilities [-]	[20, 0]	[100, 100]	[80, 80]
works council	12	Maximum walking time from a faculty building to a food facility for lunch [minutes]	[5, 0]	[2, 100]	[4, 60]
	13	Maximum walking time from a faculty building to a food facility for dinner [minutes]	[8, 0]	[3, 100]	[6, 60]
	14	Percentage of food facilities labelled diverse [%]	[0, 0]	[100, 100]	[50, 50]
	15	Average preference rating on coziness for the food facilities [-]	[0, 0]	[100, 100]	[50, 50]
social innovation	16	Percentage of places in all food facilities which can be used for working [%]	[0, 0]	[100, 100]	[50, 95]
	17	Average preference rating on find-ability of the food facilities [-]	[0, 0]	[100, 100]	[90, 90]

FIG. 5.17 Variables and coordinates of the curves relating decision variable values to preference ratings. Note adapted from Arkesteijn et al., 2017, p. 252

As can be seen this step 1, some decision makers are interested in the same variables. However, they do not give the same preference scores to the same decision variable values (**Figure 5.18**). For instance, the students want to have the food facility for lunch within a maximum walking [time] of 3 minutes, while the works council prefer this walking [time] to be 8 minutes.

food facility	student council	faculty secretary	works council
Middle	3	9	5
Large	10	18	8

FIG. 5.18 Maximum walking time in minutes per decision maker Note adapted from Arkesteijn et al., 2017, p. 253

5.1.4 Stakeholders assigned weights (step 3)

The decision makers assigned the weights to each variable that they have specified (**Figure 5.19**). The weights between the four decision makers were determined by the executive board and were split equally: therefore, each has a weight of 25%.

Both the works council and the faculty secretary give most weight to the walking time for the food facility at lunch time, respectively 30% and 35%. The works council gives 40% weight to the coziness of the food facilities, while the project leader social

innovation is interested in two variables which both receive equal weight. A closer look at the variables and their respective weights shows that there are three types of variables. Variables with regard to location, both on campus and in the building (1, 2, 4, 5, 6, 7, 8, 12, 13, 17), variables regarding the use of the food facility as work place (3, 9, 16), and variables regarding the interior design of the restaurant (10, 11, 14, 15), which respectively account for 53%, 21% and 26% of the weights.

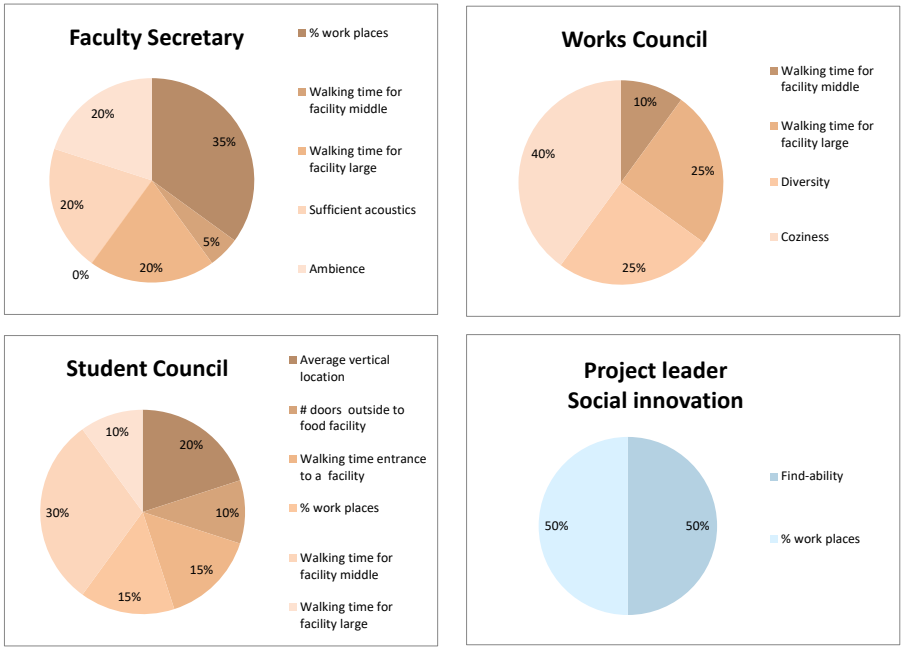


FIG. 5.19 The division of weights per variable, as determined by each decision maker. Note adapted from Arkesteijn et al., 2017, p. 254

5.1.5 Stakeholders determined design constraints (step 4)

A total of six design constraints were determined by the stakeholders. The executive board defined constraints related to variables of other stakeholders. For instance, their constraint user satisfaction is defined as the minimum average satisfaction of the preference score on the variables acoustics (10), ambiance (11) and coziness (15). These variables relate to two decision makers. The facility and real estate

TOC

department has two constraints based on costs. See **Figure 5.20** for an overview of all design constraints.

decision makers	design constraint		
Executive board 	1	Minimum availability of food facility for lunch within the maximum walking time	95%
	2	Minimum availability of facility for lunch and dinner within the maximum walking time	95%
	3	Minimum availability of facility faculty club within the maximum walking time	95%
	4	Minimum average satisfaction of the preference score on the criteria acoustics, ambience and coziness	40%
FMRE 	5	Maximum investment costs	1.850.000 euro
	6	Maximum operational costs	500.000 euro

FIG. 5.20 Design constraints Note adapted from Arkesteijn et al., 2017, p. 254

5.1.6 Stakeholders designed and chosen the best alternative (step 5a and 6)

The main objective of these step is to try to maximize the overall preference rating by designing alternatives. In step 5a alternatives are designed using the current situation as a starting point. In the current situation the decision maker can choose an intervention for each specific food facility. In this particular case the following types of real estate interventions are identified:

1. Refrain from action;
2. Remove the food facility;
3. Convert the existing food facility to new concept ‘middle’, ‘large’ or ‘faculty club’;
4. Create a new concept ‘middle’, ‘large’ or ‘faculty club’;
5. Upgrade the existing food facility.

The new concepts ‘middle’ and ‘large’ are respectively food facilities exclusively intended for lunch and for both lunch and dinner. However, because the concepts are different from the current food facilities, they have been given a different name. In this step, based on the input from step 1 to 4 and the above-mentioned interventions, a mathematical (formal) model representing the university’s food

facilities and the preferences pertaining to them, was created. The model's main interface is the map of the university showing the current situation of food facilities as well as the overall preference score of 44 for this [current] design alternative ... The design alternative with the highest overall preference score is shown in **Figure 5.21**.

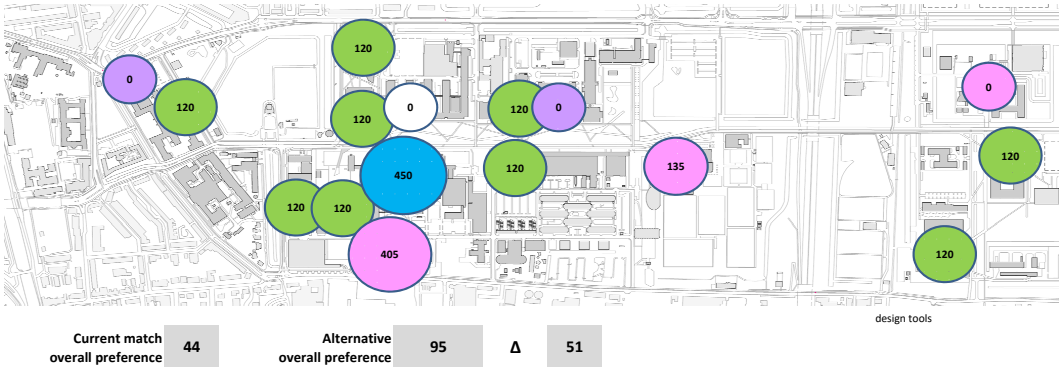


FIG. 5.21 Main interface for generating design alternatives depicting the chosen alternative. Purple circles coffee corners. Pink circles restaurants. Green circles new concept ***middle*** and blue circles new concept ***large*** Note adapted from Arkesteijn et al., 2017, p. 255

. . . The decision makers selected in step 6 the design alternative they had generated with the highest overall preference score as the best alternative (**Figure 5.21** and **Figure 5.22**). This alternative has an overall preference score of 95, which is 51 more than the current situation..

decision makers		decision variables	D_0	D_1
student council	1	Maximum walking time from a faculty building to a food facility for lunch [minutes]	0	60
	2	Maximum walking time from a faculty building to a food facility for dinner [minutes]	0	100
	3	Percentage of places in all food facilities which can be used for working [%]	3	72
	4	Average vertical location of food facility [floors]	100	100
	5	Amount of doors between outside and the food facility [doors]	52	100
	6	Average walking time from an entrance to a food facility [minutes]	60	81
faculty secretary	7	Maximum walking time from a faculty building to a food facility for lunch [minutes]	89	100
	8	Maximum walking time from a faculty building to a food facility for dinner [minutes]	0	100
	9	Percentage of places in all food facilities which can be used for working [%]	21	100
	10	Percentage of places in the facilities having sufficient acoustics [%]	21	98
	11	Average preference rating on ambience for the food facilities [-]	61	100
works council	12	Maximum walking time from a faculty building to a food facility for lunch [minutes]	60	100
	13	Maximum walking time from a faculty building to a food facility for dinner [minutes]	0	100
	14	Percentage of food facilities labelled diverse [%]	63	100
	15	Average preference rating on coziness for the food facilities [-]	45	96
pl social innovation	16	Percentage of places in all food facilities which can be used for working [%]	77	100
	17	Average preference rating on find-ability of the food facilities [-]	11	100

FIG. 5.22 Preference score per variable; current (referred to as column D_0) and chosen design alternative (referred to as column D_1) Note adapted from Arkesteijn et al.,2017, p. 256

Correct measurement of the overall preference score

The stakeholders designed an alternative with an overall preference score of 95. "The overall preference score was determined by using the weighted arithmetic mean instead of using the PFM algorithm (Barzilai, 2010). The latter is not readily available for use, and the weighted arithmetic mean is a good approximation of the overall preference score. This enabled us to give immediate feedback to the decision makers during this [pilot study]." (Arkesteijn et al., 2017, p. 247). In a later stage, the overall preference score of both the current situation (d_0) and the best alternative (d_1) have also been calculated with the PFM algorithm. As can be seen in **Figure 5.23**, the best alternative has an overall preference score of 95, the same score as calculated with the weighted arithmetic mean during the pilot study. The current situation has an overall preference score of 41, a lower score than the 44 that was calculated with the weighted arithmetic mean.

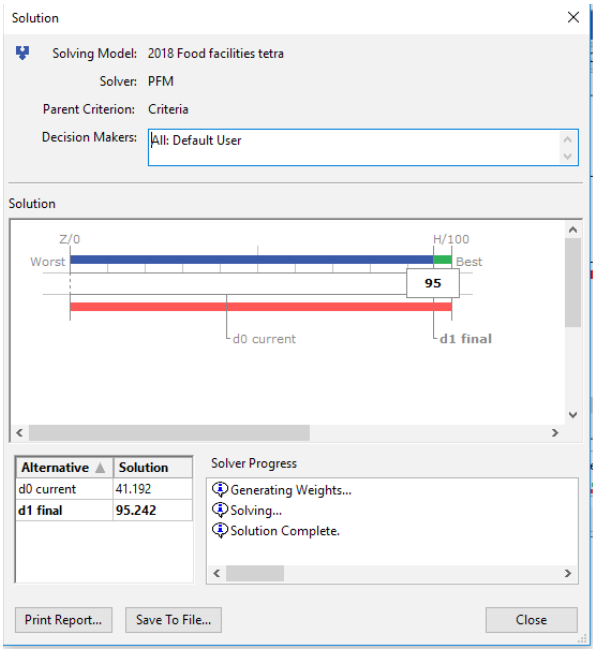


FIG. 5.23 PFM overall preference score of the current situation and the final design (Tetra)

The *best alternative* as presented in **Figure 5.21** is accepted by the stakeholders as the final outcome of the design process.

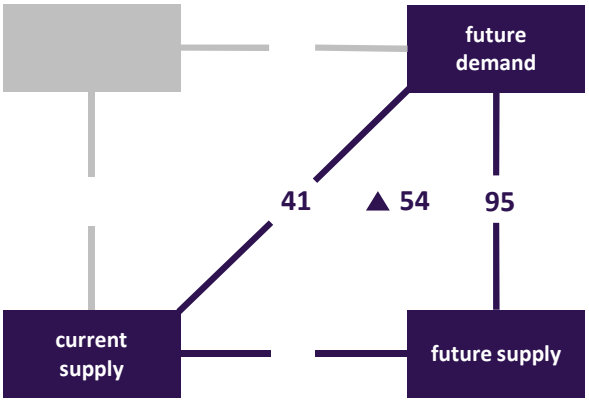


FIG. 5.24 PFM overall preference scores and added value food facilities Note adapted from De Jonge, et al., 2009, p. 36), Van der Zwart et al., 2009, p. 3., Den Heijer, 2011, p. xv.

TOC

This design alternative is selected based on the condition that concept 'middle' would not only be a coffee corner but a restaurant with warm meals as well. This was especially important for the decision makers because during the development of the pilot study the definition of the concept 'middle' was not always clear. At certain times it looked as if it would only be a coffee corner, while in the final workshop, the real estate department gave the impression it could be a restaurant with hot meals as well. Therefore, the minutes of the workshop noted this precondition (i.e. that solution is only accepted if the concept 'middle' serves hot meals).

5.2 Pilot study 2: TU Delft's lecture halls[44]

5.2.1 Introducing the pilot study

This pilot study is about the university's large lecture halls: lecture halls exceeding a capacity of 160 seats. The existing and new lecture halls are spread on the TU Delft campus as can be seen in **Figure 5.25**. At the time of the pilot study, a new lecture hall was foreseen at the south end of the campus. An impression of the halls is given in **Figure 5.26**.

This pilot study specifically concentrates on the university's large lecture halls: lecture halls exceeding a capacity of 160 seats (**Figure 5.25**). At the outset of the project, a member of the Board of Directors[45] was appointed as subject owner.

44 The results of this pilot study have been published in Arkesteijn et al., 2014, section 4 and 5, pp. 107-113. The cited text is displayed in purple and added text in black.

45 In the first pilot study, the Board of Directors is referred to as Executive Board.

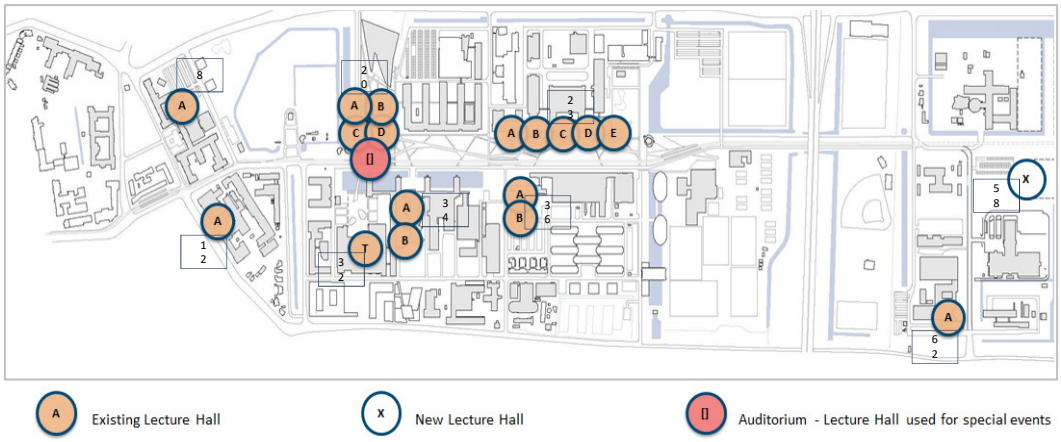


FIG. 5.25 TU Delft, large lecture halls (160+ seats) Note adapted from Arkesteijn et al., 2015 , p. 108 Building numbers are shown in the squares.

Building 20, Auditorium, room A

Building 20, Auditorium, room B

Building 20, Auditorium, room C

Building 20, Auditorium, room D

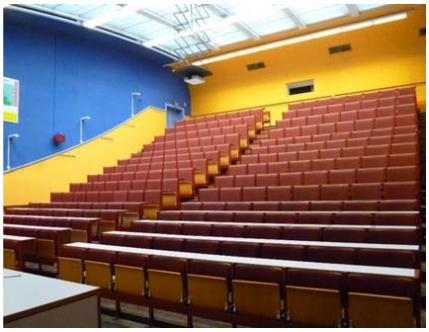
TOC

Building 23, Faculty CEG, room A

Building 23, Faculty CEG, room B

Building 23, Faculty CEG, room C

Building 23, Faculty CEG, room D



Building 12, Faculty CE - DTC, room A

Building 36, Faculty EEMCS, room A

FIG. 5.26 Figure 5.25 Photos of large lecture halls continued Note photos by Valks

The subject owner and the real estate manager find the university's lecture halls to be subject to the following four problems:

1 The current supply of lecture halls does not meet present-day requirements with regard to facilities and capacity;
2 The university is starting a new undergraduate curriculum in 2013, which will lead to a changing demand for lecture halls;
3 There are too few types of educational facilities to accommodate this changing demand;
4 The current supply is being used ineffectively: occupancy and utilization rates of lecture halls suggest that an increase in efficiency is possible.

At the time of the pilot study no specific vision, similar to the living campus vision, existed for the educational spaces[46]. The design and decision model must establish a relationship between the demand for educational space and the supply of lecture halls. This relationship can be seen as an indirect relationship (see **Figure 5.27**). Indirect firstly because, the teachers give their demand for educational space. They state their demand for lecture halls based on amongst others their type course (lectures, working groups etc.) and the amount of students they expect. Secondly, this demand is processed by Education and Student Affairs (E&S Affairs) who allocates all courses to a timetable. When making their timetable they use the available lecture halls that have been allocated to them by the FMRE department This means that timetabling forms a significant part of problem in the pilot study of the lecture halls.

These three different types stakeholders have, as it showed during the pilot study, conflicting interests. Where the teachers and E&S affairs (often) experience a shortage of space, the FMRE department measure a low(er) occupancy and frequency rates of the lecture halls. The basic tensions between the stakeholders are shown in **Figure 5.28**. Subsequently, during the pilot it also showed that they expect that the solution needs to be provided by another party.

46 The pilot project has served as an input to create university policy on educational spaces: the university's 'Roadmap Education Spaces' (2014).

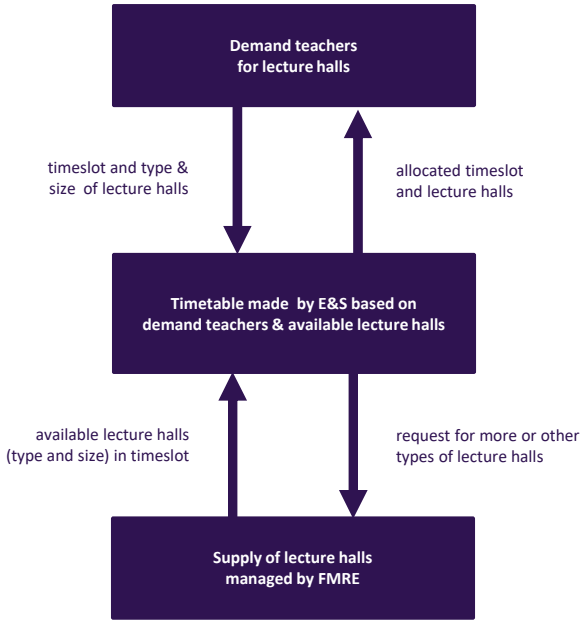


FIG. 5.27 Relationship demand for educational space and supply of lecture halls

In the pilot study not only the abovementioned teachers, E&S Affairs and the FMRE department were involved. **Figure 5.29** displays the stakeholders that participated in the pilot. Some stakeholders consisted of multiple participants (e.g. Education and Student Affairs) whilst others consisted of only one participant (e.g. Board of Directors).

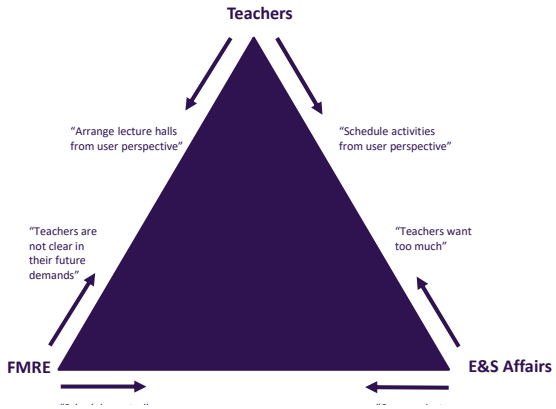


FIG. 5.28 Tensions between teachers, E&S Affairs and FMRE

TOC

	stakeholders	examples of criteria
	Board of Directors	Student satisfaction, teacher satisfaction
	Directors of Education	Students in own faculty, availability SMARTboard
	Facility Management and Real Estate	Running costs, occupancy rate
	Student Council	Evening lectures, lectures in own faculty
	Teacher Board	Student walking distance, availability SMARTboard
	Education and Student Affairs	Occupancy rate, Match students/capacity lecture hall

FIG. 5.29 Participating stakeholders in the pilot study Note from Arkesteijn et al., 2015 , p. 109

5.2.2 Stakeholders specified decision variables (step 1)

The criteria defined by each stakeholder (**Table 5.6**) reveal that the performance of the university's lecture halls depends only partly on the amenities available in the lecture hall. A large part of the performance also depends on the way the lecture halls are used by the university. The users of the lecture halls are generally concerned about the amenities in the lecture halls and the vicinity of the lecture hall to their workplace. The technical managers focus on the efficiency of the portfolio (occupancy rate, costs) while the Board of Directors is interested in both efficiency and satisfied users.

With regard to the amenities in lecture halls, the criteria reveal that some amenities are found to be important or even necessary by multiple users: examples include modern teaching amenities such as Collegerama and four-quadrant beamers. Collegerama is an apparatus for recording lectures, whilst a four-quadrant beamer allows the teacher to work with four separate projections. Other amenities, such as power outlets for laptop use or comfortable chairs are not mentioned at all.

5.2.3 Stakeholders determined preference curves (step 2)

For each variable, the stakeholders determined in step 2 a bottom reference alternative (x_0, y_0), a top reference alternative (x_1, y_1) and an intermediate reference alternative (x_2, y_2). The preference ratings displayed in the **Figure 5.31** correspond with the preference ratings at the end of the second workshop.

As an example, **Figure 5.30** displays preference ratings of the participant 'Education and Student Affairs to the criterion 'occupancy rate.'[47] In **Figure 5.30**, the bottom reference alternative (x_0, y_0) is set at 100 percent, because the participant has no flexibility left in the timetable if the occupancy rate of the lecture halls is 100 percent. The top reference alternative (x_1, y_1) is set at 70 percent, because the department's experience is that this leaves enough room in the timetable for extracurricular and/or unforeseen events.

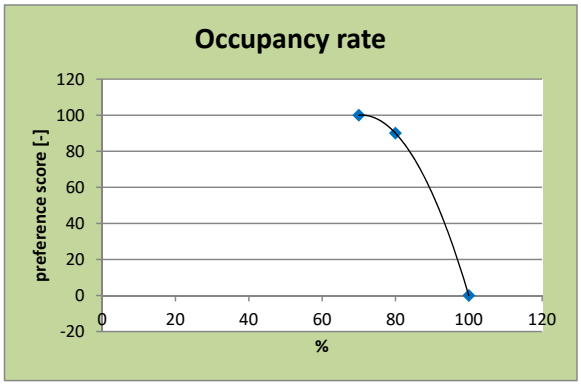


FIG. 5.30 Lagrange curve relating preference rating to the occupancy rate (criterion 32) of the university's portfolio of lecture halls Note from Arkesteijn et al., 2015 , p. 111

decision makers		criteria	bottom reference (x_0, y_0)	top reference (x_1, y_1)	intermediate reference (x_2, y_2)
Board of Directors	1	Education in small groups (% of total hours scheduled)	[0, 0]	[50, 100]	[40, 80]
	2	Student satisfaction (% of preference score on criteria 13-21)	[45, 0]	[85, 100]	[75, 80]
	3	Teacher satisfaction (% of preference score on criteria 22-29)	[45, 0]	[85, 100]	[75, 80]
	4	Occupancy rate (hours scheduled / capacity in hours)	[30, 0]	[70, 100]	[55, 80]
Directors of Education	5	First year students: lectures in own faculty (% of total hours scheduled)	[25, 0]	[90, 100]	[70, 75]
	6	Second year students: lectures in own faculty (% of total hours scheduled)	[20, 0]	[60, 100]	[40, 70]
	7	Third year students: lectures in own faculty (% of total hours scheduled)	[0, 0]	[20, 100]	[10, 4]
	8	Appropriate classroom size (ratio between students and lecture hall capacity)	[150, 0]	[100, 100]	[120, 60]
	9	Availability of four-quadrant beamer (% of lecture halls)	[30, 0]	[100, 100]	[60, 80]

FIG. 5.31 Criteria and their respective preferences Note adapted from Arkesteijn et al., 2015 , pp. 110-111

47 The criterion occupancy rate shows that revealed preferences of the past (low occupancy rates) can also be used as design criterion. This reflects in the preference ratings.

decision makers		criteria	bottom reference (x_0, y_0)	top reference (x_1, y_1)	intermediate reference (x_2, y_2)
Directors of Education (continued)	10	Availability of blackboard and beamer (% of lecture halls)	[80, 0]	[100, 100]	[90, 60]
	11	Availability of flexible chairs (% of lecture halls)	[0, 0]	[30, 100]	[15, 60]
	12	Education in small classrooms (% of lecture halls)	[2, 0]	[12, 100]	[8, 70]
Student Council	13	Amount of lectures recorded (Collegerama) (% of lectures in lecture halls with Collegerama)	[75, 0]	[100, 100]	[80, 30]
	14	Amount of lectures in the evening (% of lectures scheduled after 5:00 PM)	[2, 0]	[0, 100]	[1, 40]
	15	Amount of movements between buildings (% of total lectures in another building than previous)	[3, 0]	[0, 100]	[2, 20]
	16	Lectures in own faculty (% of total hours scheduled)	[50, 0]	[100, 100]	[75, 60]
	17	First year students: lectures in own faculty (% of total hours scheduled)	[25, 0]	[90, 100]	[75, 70]
	18	Second year students: lectures in own faculty (% of total hours scheduled)	[20, 0]	[80, 100]	[50, 70]
	19	Third year students: lectures in own faculty (% of total hours scheduled)	[0, 0]	[50, 100]	[25, 20]
	20	Availability smartboard or four-quadrant beamer (% of lecture halls)	[20, 0]	[100, 100]	[50, 30]
	21	Flexible lecture halls (% of lecture halls)	[0, 0]	[30, 100]	[15, 60]
Teachers	22	Standard equipment (% of lecture halls)	[0, 0]	[100, 100]	[50, 40]
	23	Blackboards/whiteboards (% of lecture halls)	[50, 0]	[100, 100]	[80, 60]
	24	Flexible chairs (% of lecture halls)	[30, 0]	[80, 100]	[60, 60]
	25	Walking distance for students (minutes)	[15, 0]	[5, 100]	[10, 25]
	26	Amount of lectures recorded (Collegerama) (% of lectures in lecture halls with Collegerama)	[0, 0]	[100, 100]	[80, 90]
	27	On-site assistance (minutes)	[10, 0]	[2, 100]	[5, 20]
	28	Assistance in transport of teaching materials (hours)	-	-	-
	29	Reservation of parking spots (% of parking spots available on-demand for teachers)	[0, 0]	[100, 100]	[20, 20]
E&S Affairs	30	Walking distance for students (minutes)	[15, 0]	[5, 100]	[10, 50]
	31	Appropriate classroom size (ratio between students and lecture hall capacity)	[150, 0]	[100, 100]	[125, 80]
	32	Occupancy rate (hours scheduled / capacity in hours)	[100, 0]	[70, 100]	[80, 90]
	33	Functionality of lecture hall equipment (% of total hours in which there are no defects)	[95, 0]	[99, 90]	[100, 100]
FMRE	34	Occupancy rate (hours scheduled / capacity in hours)	[0, 0]	[70, 100]	[40, 50]
	35	Appropriate classroom size (ratio between students and lecture hall capacity)	[50, 0]	[90, 100]	[75, 80]
	36	Running costs (€)	[130, 0]	[100, 100]	[110, 80]

FIG. 5.31 Continued

5.2.4 Stakeholders assigned weights (step 3)

The weights the stakeholders assigned to each criterion are displayed in **Figure 5.32** below. The weights between the stakeholders were determined by the board of directors to be split equally: therefore each stakeholder has a weight of 16.67%.

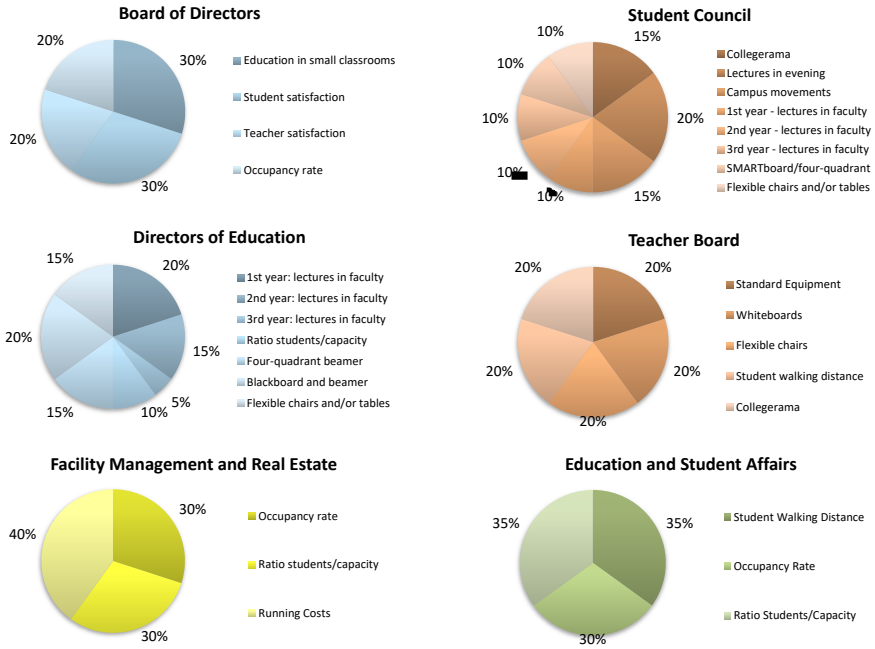


FIG. 5.32 The division of weights per criterion, as determined by each stakeholder Note Arkesteijn et al., 2015 , p. 112

5.2.5 Stakeholders determined design constraints (step 4)

A total of five design constraints were determined by the stakeholders, mostly related to scheduling issues rather than real estate issues. What the design constraints also reveal is that for Education and Students Affairs, the priority is to timetable all the university's activities within the specified constraints. Once this is achieved, a certain efficiency is desirable (see criteria): i.e. finding a good student/capacity ratio only becomes important after a solution is found that incorporates all design constraints (See **Figure 5.33**).

decision makers	design constraint	
Student Council	1	Two-way interaction with the teacher at all times
	2	The amount of students present cannot exceed the lecture hall capacity
E&S Affairs	3	DUT must have enough capacity to accommodate all mandatory activities
	4	The maximum amount of scheduled hours per student per day is eight hours
	5	Mandatory courses cannot be scheduled at the same time

FIG. 5.33 Design constraints incorporated into the scheduling model Note adapted from Arkesteijn et al., 2015 , p. 112

5.2.6 Stakeholders designed and chosen the best alternative (step 5a and 6)

The main objective of designing alternatives is to maximize the overall preference rating. In this particular case two types of interventions are possible: organizational and real estate interventions. With regard to the timetable, the following organizational interventions are possible:

- Set boundary conditions on the percentage of lectures in the own faculty;
- Enable/disable scheduling in the evening hours;
- Enable/disable scheduling in the lunch hours;
- Set the allowed walking distance between lectures to 5, 10 or 15 minutes;
- Enable/disable the new education programs in the bachelor phase; enabling will lead to less lectures;
- Set the amount of options given by the teacher for a suitable moment to high, medium or low;
- Vary the amount of total students on the campus.

Table 5.2 shows the values of these interventions in the current situation (design alternative d_0) and in the resulting design alternative of the second workshop. In the workshops, the first objective for the participants was to maximize the amount of lectures in the own faculty. Because fixing these values leads to a reduction of the feasible set [48], other variables were set to increase flexibility: adding new bachelor programs, increasing walking distance and the amount of options (in time) given by the teachers.

48 In the mathematical model, the feasible set refers to the set of decision variables that can be set to a value of one. The smaller the feasible set, the less likely it is that the model is able to generate a feasible solution.

TABLE 5.2 Scheduling result, for design alternative d_0 [current] and d_1 [future]. The input value can be changed by the decision makers to optimize the scheduling result (layout adapted) Note from Arkesteijn et al., 2015 , p. 114

Variable	Current (Design alternative d_0)		Future (Design alternative d_1)	
	Input value	Scheduling result	Input value	Scheduling result
1a First-year students in own faculty	Unconstrained	47%	>= 65%	65%
1b Second-year students in own faculty	Unconstrained	28%	>= 40%	40%
1c Third-year students in own faculty	Unconstrained	15%	>= 15%	15%
2 Lectures in evening hours	Not possible	0%	Not possible	0%
3 Lectures in lunch hours	Not possible	0%	Not possible	0%
4 Allowed walking distance	Max. 5 minutes	4.7 minutes on average	Max. 15 minutes	5.2 minutes on average
5 New bachelor programs	Off	496 lectures per week	On	425 lectures per week
6 Amount of options given by teacher	Low	6,830 possible time slots for 496 lectures	High	12,639 possible time slots for 425 lectures
7 Amount of students	= 100%	-	= 100%	-

With regard to real estate, a range of interventions could be applied to each lecture hall:

1. Remove lecture hall;
2. Do nothing;
3. Renovate lecture hall (by doing one or more of the following)[49];
    a. Add power sockets;
    b. Add internet;
    c. Add four-quadrant beamer;
    d. Add blackboard;
    e. Add whiteboard;
    f. Add smartboard;
    g. Add Collegerama (recording device);
    h. 1. Add swiveling chairs;
    i. 2. Add flexible chairs and tables;
4. Add new lecture hall.

49 The numbers A to H2 have been added, because they have not been displayed in the paper.

Figure 5.34 displays the portfolio of lecture halls in the current and future design alternatives. With the exception of lecture hall 1 all the existing lecture halls have been renovated. Lecture hall 19 could have been added to the portfolio if necessary, but in the design alternative this option was not used. The combination of design interventions in the timetable and the lecture halls yielded the following design result per criterion (**Figure 5.35**).

FIG. 5.34 Portfolio result, current and future. The numbers A-H2 correspond with the interventions named above Note from Arkesteijn et al., 2015 , p. 115

The stakeholders designed an alternative with an overall preference score of 69 (also referred to as d_1 and future design), based on the weighted arithmetic mean. The overall preference score for the current situation is 58. This means that the added value in this pilot was 11. The added value is calculated as follows: overall preference score for the final design (69) minus overall preference score for the current situation (58).

TOC

decision makers		criteria	current situation	future design alternative
Board of Directors 	1	Education in small groups	87	100
	2	Student satisfaction	0	43
	3	Teacher satisfaction	57	88
	4	Occupancy rate	100	94
Directors of Education 	5	First year students: lectures in own faculty	40	68
	6	Second year students: lectures in own faculty	33	70
	7	Third year students: lectures in own faculty	35	53
	8	Appropriate classroom size	25	17
	9	Availability of four-quadrant beamer	0	88
	10	Availability of blackboard and beamer	79	100
	11	Availability of flexible chairs (% of lecture halls)	0	69
	12	Education in small classrooms (% of lecture halls)	-	-
Student Council 	13	Amount of lectures recorded (Collegerama)	0	93
	14	Amount of lectures in the evening	100	100
	15	Amount of movements between buildings	66	72
	16	Lectures in own faculty (% of total hours scheduled)	0	0
	17	First year students: lectures in own faculty	-	-
	18	Second year students: lectures in own faculty	-	-
	19	Third year students: lectures in own faculty	-	-
	20	Availability smartboard or four-quadrant beamer	9	56
	21	Flexible lecture halls (% of lecture halls)	0	69
Teachers 	22	Standard equipment (% of lecture halls)	92	100
	23	Blackboards/whiteboards (% of lecture halls)	65	100
	24	Flexible chairs (% of lecture halls)	0	0
	25	Walking distance for students (minutes)	100	96
	26	Amount of lectures recorded (Collegerama)	69	99
	27	On-site assistance (minutes)	-	-
	28	Assistance in transport of teaching materials	-	-
	29	Reservation of parking spots	-	-
E&S Affairs 	30	Walking distance for students (minutes)	100	98
	31	Appropriate classroom size	37	25
	32	Occupancy rate	37	25
	33	Functionality of lecture hall equipment	-	-
FMRE 	34	Occupancy rate	100	88
	35	Appropriate classroom size	72	68
	36	Running costs (€)	-	-
total			**58**	**69**

FIG. 5.35 Preference score per variable; current (d_0) and future design alternative (d_1) Note from Arkesteijn et al., 2015 , p. 116

Correct measurement of the overall preference score

As explained in the first pilot, "the overall preference score was determined by using the weighted arithmetic mean instead of using Barzilai's PFM algorithm" (Arkesteijn et al., 2017, p. 247). In a later stage, the overall preference score of both the current situation (d_0) and the best alternative (d_1) have also been calculated with Barzilai's PFM algorithm. As can be seen in **Figure 5.36**, **Figure 5.37** the best alternative has an overall preference score of 70 (69,769). This is very close to the overall preference score of 69 that was calculated with the weighted arithmetic mean during the pilot study. The current situation has an overall preference score of 53 (52,635), a lower score than the 58 that was calculated with the weighted arithmetic mean.

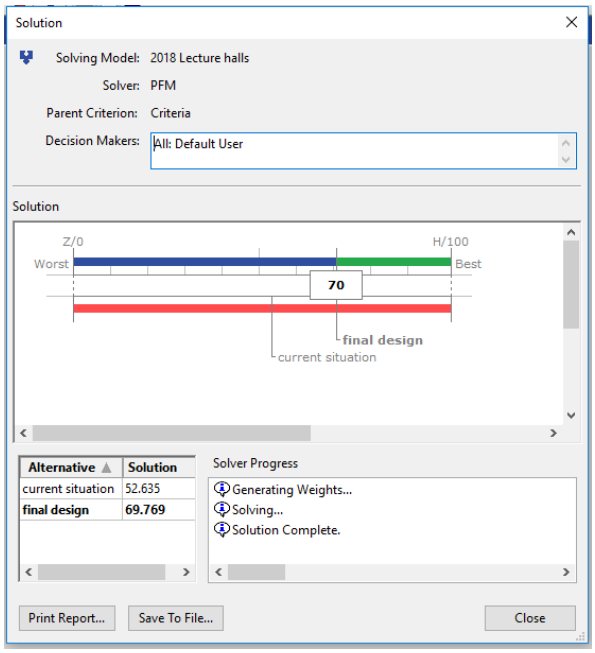


FIG. 5.36 PFM overall preference score of the current situation and the final design (Tetra)

The best alternative as presented in **Figure 5.35** (also referred to as d_1 final) is accepted by the stakeholders as the final outcome of the design process. This alternative has an overall preference score of 70 (PFM algorithm) for the final design alternative and an overall preference score of 53 for the current situation. The added value is 17.

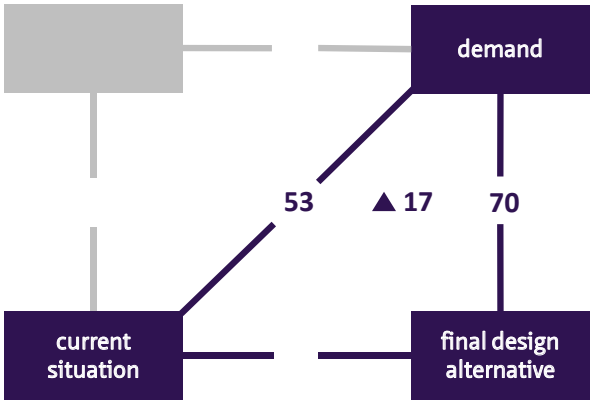


FIG. 5.37 PFM overall preference scores current situation and best alternative as well as added value lecture halls Note adapted from De Jonge, et al., 2009, p. 36, Van der Zwart et al., 2009, p. 3, Den Heijer, 2011, p. xv.

5.3 Pilot study 3: Oracle's office locations

The third pilot study was conducted at Oracle, a multinational ICT company, by graduate student De Visser in 2016. This pilot study is presented in this thesis for four reasons:

- Firstly, to show that PAS can be successfully used in a different type of organization. Oracle is a multinational company and differs a lot from the context of a public university.
- Secondly, that PAS can also be used for a different type of problem. The problem in this pilot was the choice of a new office location.
- Thirdly, Oracle currently uses a scorecard process for the selection of new office locations. This scorecard process is an advanced system to make well-funded decisions in a transparent process. From the perspective of the preference measurement paradigm, as explained in chapter 3, their process does not make use of strong scales. This makes it possible to compare the PAS procedure to the original scorecard process. Does PAS reflect the stakeholders preferences better than the current process? And are the results of PAS better than the current outcome.
- And lastly, in the Oracle pilot an optimization tool has been tested. This makes it possible to determine on the one hand if it is possible to achieve better results with an optimization tool than with the PAS design and on the other hand whether the results from the optimization tool are acceptable for the stakeholders.

This pilot study was confidential therefore only the final results of the pilot will be presented anonymously. This means that step 6 will be discussed but that the results of the previous steps will not be presented here. The pilot is extensively reported in De Visser (2016) and De Visser, Arkesteijn, Binnekamp, and De Graaf (2017). The pilot study is introduced in paragraph 5.3.1 and the results are shown in paragraph 5.3.2.

5.3.1 Introducing the Oracle pilot study office locations

In this pilot study there was an unique opportunity to compare PAS to the current office location decision process. Therefore the current decision making process will be introduced more extensively. Subsequently, the company and its corporate real estate management, the current real estate location decision making process, the specific case and the pilot study will be described. This paragraph is based on De Visser, 2016, pp. 59-63[50].

Oracle and its corporate real estate management

Oracle[51] is a globally operating ICT company that provides its services in more than 145 countries. They provide hardware, software and data storage services to a range of industries, from education and banking to high tech engineering companies and the public sector. ... Altogether, the company has more than 130.000 employees, spread over four global regions with total revenues of US$38.2 billion over 2015. All employees and data servers need accommodation and the portfolio should stay aligned with the business (De Visser, 2016, p. 58).

Real estate strategy making and alignment to the business is done by the Advanced Planning (AP) Team. The real estate departments of the four global regions take care of the execution of the strategy, accompanying transactions and possible interventions. In general Oracle's real estate organization maintains close ties with the business, with the result that [line of businesses] LOBs contact the organization in case they want to make considerable changes in their portfolio. This improves the control over the execution of a high-level real estate strategy. The alignment

50 The long citations and summarised text are displayed in purple.

51 De Visser based the content of his chapter on an interview about corporate real estate (CRE) alignment held by Arkesteijn and Kuijpers with Smith, vice president Global Real Estate and Facilities at Oracle. As well as project meetings with De Visser's mentors Leipner-Srebnick, director Real Estate Advanced Planning, and Davenport, Global Location Strategy Programme manager within at Oracle's Advanced Planning team.

between the real estate and the business is maintained by monitoring a lot of object characteristics, the resulting data is made insightful in a dashboard environment and is reported monthly. In addition to these reports, the organization keeps track of the effects of planned interventions on the portfolio in a so-called Plan of Records that shows the development of the portfolio over time. This tool is used to evaluate the decisions and provide insight in when they will influence the portfolio data. … In addition to the studies, the real estate department works with a mission statement that is shared among the regional real estate departments to be used in their daily activities. Furthermore certain targets are connected to the data that is monitored, which can be used to decide upon interventions to improve the alignment (De Visser, 2016, p. 58-59).

The current real estate location decision making process

The AP team conducts roughly two types of studies; the low cost location studies per global region and LOB specific studies upon request of a specific LOB. LOBs ask the AP team to view the results of a low cost study in their region and pick a location after having had the possibility to adapt the weights that were initially assigned to the variables. In this way, the AP team keeps track of the alignment of the LOBs with the study outcomes. Sometimes, the presentation of a low cost study results in an additional study for the specific LOB, often because they search for a different location with other criteria (De Visser, 2016, p. 59). See **Figure 5.38**.

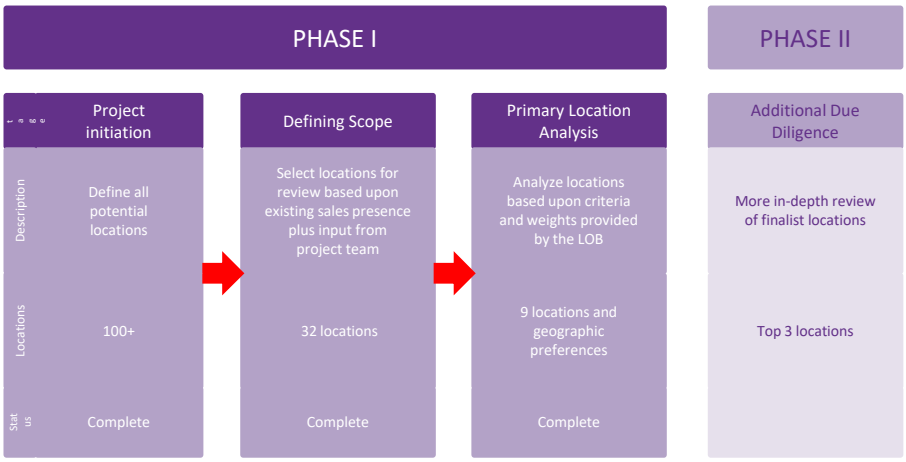


FIG. 5.38 The process followed in [original] study Note adapted from Davenport in De Visser, 2016, p. 60

TOC

The Advanced Planning (AP) team conducts specific location studies in order to identify locations, i.e. cities or metropolitan areas, where a Line of Business (LOB) can expand its activities. The team uses a scorecard process in order to rate a selection of locations on a set of criteria with weights that are adapted by the LOB. The LOB then selects a location from the resulting ranking of locations (De Visser, 2016).

The case

The case used in this research and design project consists of an LOB specific location study, conducted by the AP team. The original study started upon the request of LOB 1 to propose up to three locations for a new hub in the global region covering Europe, Middle- East and Africa (EMEA). LOB 1 is expecting to grow considerably in the coming years, which means that the current portfolio is not able to accommodate the increasing number of employees. The new hub should be operational in 2018. The general aim of the new hub is to attract millennials, a generation of people that is born around the time of the millennium, i.e. the year 2000, and is grown up with computers, smartphones and the internet. The main variable for the location is the attractiveness to native English speakers, in addition to this, costs should be taken into account as a less influential criterion. Based on the request by LOB 1, the AP team previously established a set of criteria, making use of a report3 that presents a set of indicators that are found to attract millennials to cities (De Visser, 2016, p. 61). (see **Figure 5.39**)

In this case the AP team defined 39 criteria including some cost criteria. All criteria were confirmed by the representative of the LOB, who also assigned the weights to the criteria. The AP team then proceeded with searching for the required data for each of the criteria and assigned the arrays covered by the 1-5 scale, just like in the low cost studies. The arrays were checked globally by the LOB, however, they mostly relied on the assessment of the AP team. After the rating was established, the locations were rated based on the data, and the weighted average rating was calculated. The representative of the AP team indicated however, that it was rather complex for the stakeholders to determine the appropriate weights for the criteria. After the outcome of the scorecard was known, a selection of the nine best-rated locations (current locations excluded) was assessed in more detail on an additional set of qualitative aspects. This resulted in a set of strengths and weakness per location, that was used to make the recommendation for a final selection of three location alternatives. Based on this selection, the final decision for a new location was made by the representative from the LOB (De Visser, 2016, p. 60).

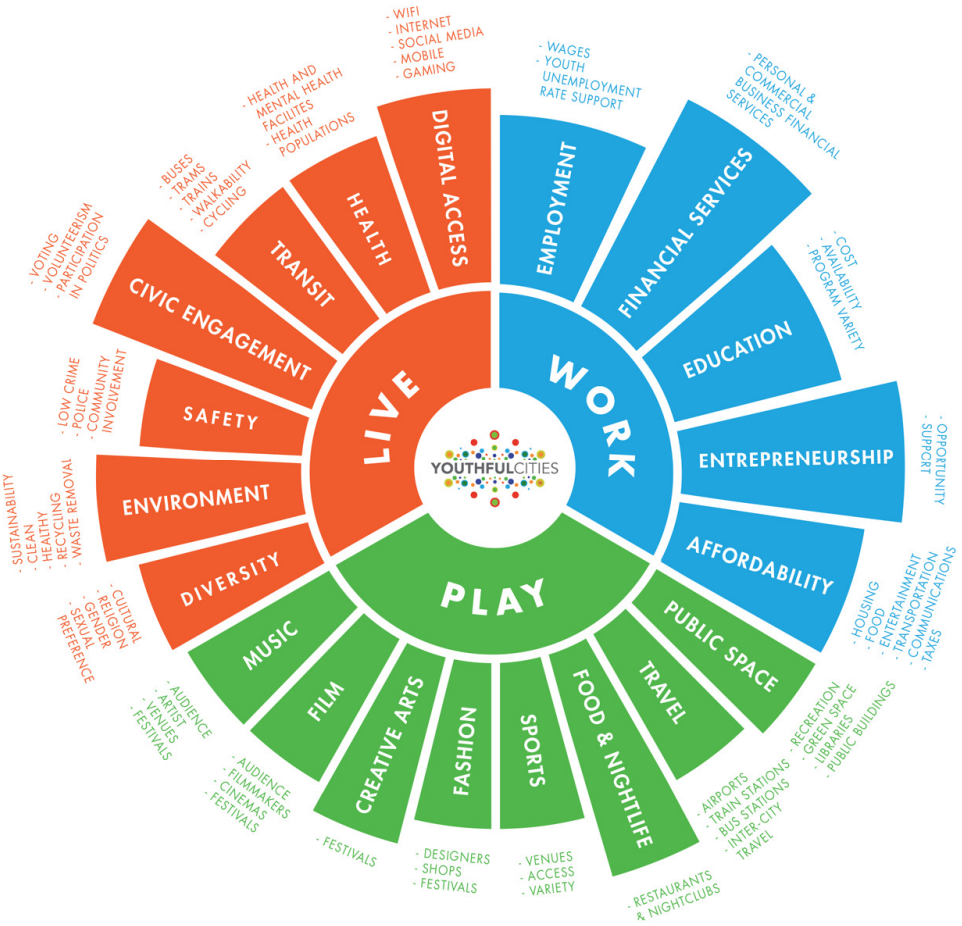


FIG. 5.39 Indicators for attracting millennials Youthful-Cities in De Visser, 2016, p. 61

The pilot study

The original scorecard comprised of 39 variables that are sorted in five categories. Each category is connected to a weighing. The scorecard takes the average of the variables ratings in each category to calculate the category rating. The weighted average of those five category ratings provides the overall rating for each location. However, to make the case better to handle and because multiple variables cover the same aspects, a selection of 22 variables is made for this pilot study. This selection is made in such a way that for all five categories a representative set of variables remains (De Visser, 2016, p. 62). (see **Table 5.3**)

TOC

TABLE 5.3 Categories of interest covered by criteria Note from De Visser, 2016, p. 62

Categories of interest
Costs
Ease of sourcing native speakers & millennials
Labor environment
Fit to LOB 1 EMEA vision and value proposition
Government support

5.3.2 Stakeholders chosen the best alternative (step 6)

Before the results are presented, it is good to remember that in this pilot three alternatives have been designed and compared to the current portfolio.

1. The first alternative is the LOB's current choice as output of their own scorecard process (referred to as *LOB's choice)*;
2. The second alternative is the optimum feasible portfolio alternative designed by the stakeholders (referred to as *Optimum design)*;
3. The third alternative is the alternative that has been generated by the optimization tool (referred to as *Global optimum)*.

The results for all alternatives are presented in **Table 5.4**.

The number one portfolio alternative, Global optimum, has a higher preference rating than found by the stakeholders. The Global optimum portfolio alternative provides an improvement of 7% in the preference rating over the current portfolio, whereas the optimum found through design achieves an improvement of 5% (De Visser, 2016, p. 85).

The *Optimum design* is accepted by the stakeholders as the final outcome of the design process, which confirms that the model closely reflects their preferences. Later, after the Global optimum has been presented to them, the stakeholders indicated that they expected such an outcome and accept this as the final outcome of the pilot study. This shows that it is possible to find a portfolio alternative with a better preference rating than the stakeholders are able to find. Compared to Oracle's current scorecard system, the location ranking from the PAS model showed an improvement in the representation of the users' location preferences, induced by the use of preference curves (De Visser, 2016).

TABLE 5.4 Comparison of optimum portfolio alternatives to the current portfolio and the actual choice by LOB 1 Note adapted from De Visser, 2016, p. 83 legend: Locations in purple are part of 3 or more alternatives

Name	Current portfolio	LOB's choice	Optimum design (step 5a)	Global optimum (step 5b)
Locations	Location 5	Location 5		
			Location 8	
	Location 10	Location 10	Location 10	Location 10
		Location 13	Location 13	Location 13
			Location 17	Location 17
	Location 18	Location 18		
				Location 21
	Location 25	Location 25	Location 25	
				Location 27
	Location 31	Location 31	Location 31	Location 31
	Location 32	Location 32	Location 32	Location 32
Overall preference score	*61*	**63**	**64**	**66**
Difference	-	**3%**	**5%**	**7%**
			change of 2 other locations as well	change of 3 locations

The results of this pilot study have also been presented in **Figure 5.40**. The *best alternative* for this pilot was the *global optimum* and this alternative was accepted by the stakeholders as the final outcome. It must be noted, that in this pilot less interventions were possible (to add or remove a location) which partly influenced the amount of added value could be achieved. This alternative *global optimum* has an overall preference score of 66 (PFM algorithm) compared to the overall preference score of 61 for the current situation. The added value therefore is 5, more than twice the added value than the current process.

This means that PAS can also be successfully used in a different type of organization for a different type of problem. In comparison to Oracle's current scorecard process, PAS performs better than the original. In this pilot, it was possible to achieve a better result with the optimization tool (step 5b) than with the PAS design (step 5a), and the stakeholders accepted that result.

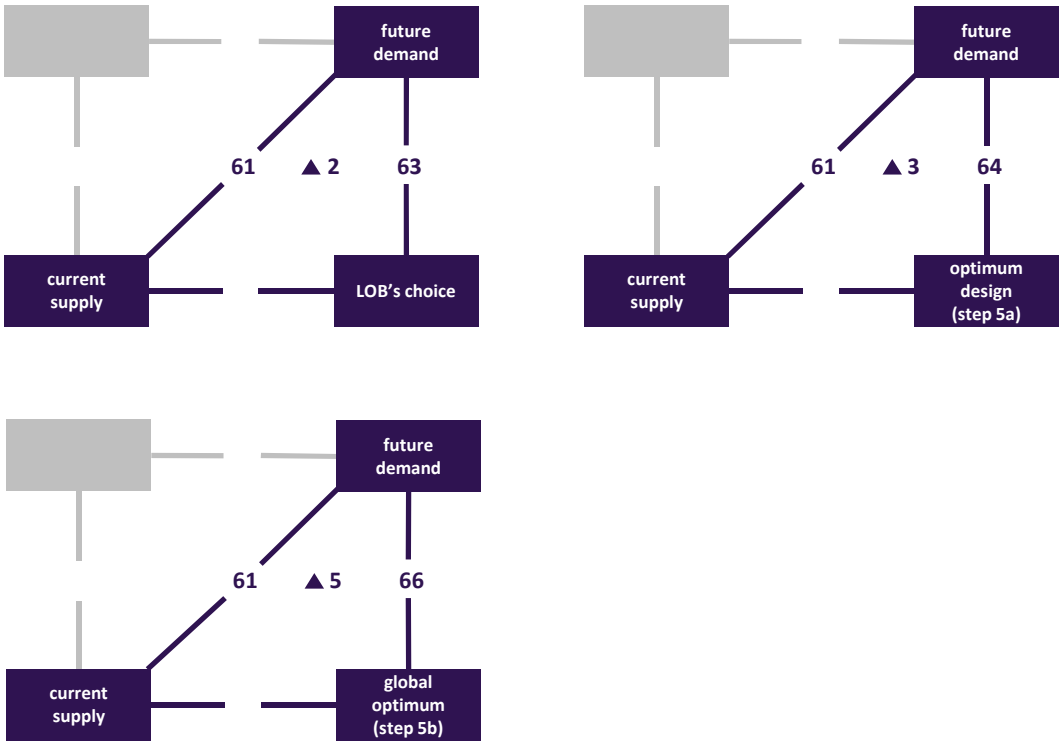


FIG. 5.40 PFM overall preference scores current situation and optimum design (step 5a) and global optimum (step 5b) as well as added value office locations Note adapted from De Jonge, et al., 2009, p. 36, Van der Zwart et al., 2009, p. 3, Den Heijer, 2011, p. xv.

The uniqueness of this pilot made it possible to compare the PAS results with their current decision making process (Phase I in **Figure 5.38**). This pilot study also gives an indication that PAS and especially the use of the curves, to express demand, reflects the stakeholders preferences better than the current process. This can be concluded based on the LOB's choice and the comparison rankings that De Visser made (see **Figure 5.41**). De Visser looked at the rankings instead of an overall score because the original study resulted in a ranking instead of a score (De Visser, 2016).

The comparison between the original ranking and PAS showed that roughly two third of the top-15 locations in the original study returns in the top-15 of the PAS outcome. Moreover, the chosen location 13 moved from place 17 in the original ranking to place 4 in the PAS ranking (in **Figure 5.41** this is the comparison between study 5 and 1). The chosen location is the second most preferred location that is not included in the current portfolio. This is an initial indicator that the PAS model

quite closely reflects the stakeholders' preferences in a more accurate way than the original scorecard procedure (De Visser, 2016).

study type	original study				PAS
comparison	A. effect of different criteria		C. effect of change of weight stakeholder		
		B.effect of weighted average to original		D. effect of the use of preference curves	
study number	1	2	3	4	5
number of criteria	39	22	22	22	22
calculation	procedure scorecard	procedure scorecard	weigthed average	weigthed average	PAS
weights	original	original	original	new	new
position chosen location (ranking)	17	13	13	10	4
difference w.r.t. previous ranking		4	0	3	6
difference w.r.t. ranking 1			4	7	13

FIG. 5.41 Comparison PAS and original scorecard study Note adapted from de Visser, 2016, p. 75

It must be noted that the use of the PAS curves was not the only change compared to the current scorecard process. Therefore other factors also influenced the better representation. In order to make a comparison De Visser (2016) made the comparison as is shown above. The changes were:

A The amount of criteria decreased (from study 1 to 2) and resulted in a higher ranking of the chosen location of 4 places;
B The way the overall score was calculated changed (from study 2 to 3) and resulted in the same ranking of the chosen location;
C In study 4 each criterion received a weight while in the original study the weights were given to a set of criteria (from study 3 to 4). This resulted in a higher ranking of the chosen location of 3 places;
D In study 5 the preference curves were new. This resulted in a higher ranking of the chosen location of 6 places (De Visser, 2016).

Having that said, the chosen location scored better in phase I[52] with PAS than with the current scorecard process, a higher ranking of 13 places. A difference of 13 places (between position 17 and 4) in PAS quals a location preference scores of 68 (ranking 4) and 53 (ranking 17) (De Visser, 2016).

52 In phase II of Oracle's current process the chosen location received a higher position

5.4 Pilot study comparison and conclusion

The PAS is tested in three pilot studies to determine if the stakeholders are able to successfully perform PAS. All pilot studies show that the stakeholders were able to perform each step of PAS, including the new step 2 (determining preferences) and step 5a (design alternatives). The stakeholders were able to design an alternative CRE portfolio with a higher overall preference than in the current situation. This means that they were able to better align their CRE portfolio to the organization. The pilots respectively have an added value, expressed in an overall preference score, of 54, 17 and 3 (see **Table 5.5**). In step 6 all stakeholders accepted that alternative as the final outcome.

TABLE 5.5 Pilot comparison achieved added value alternative CRE portfolio design (step 5a)

Results (based on PFM algorithm)	1st pilot study Food facilities	2nd pilot study Lecture halls	3rd pilot study office location
Overall preference score current portfolio	41	53	61
Overall preference score alternative design	95	70	64
Added value	54	17	3

In two pilots an alternative CRE portfolio has been generated with an optimization tool (see **Table 5.6**). In the Oracle pilot, the brute force approach was able to generate an alternative with a higher overall preference score (66) than the current situation (61) and the design (64). As a reminder, the overall preference score is in between 0 and 100. In the TU Delft food facilities pilot, the search algorithm was not able to generate a *feasible alternative* with a higher overall preference score.

The Oracle pilot also showed that PAS performed better than their current location decision making process. The overall preference score of their chosen alternative was 63, while the optimization tool was able to achieve an overall preference score of 66. This was due to the fact that in the current process one new location was added to the portfolio, while in the PAS the total EMEA portfolio has been optimized. This means that more than one location was changed.

TABLE 5.6 Pilot comparison achieved added value alternative CRE portfolio design generated by optimization tool (step 5a&b)

Results (based on PFM algorithm)	1st pilot study food facilities	3rd pilot study Office location
Overall preference score current portfolio (a)	41	61
Overall preference score alternative design (step 5a) (b)	95	64
Overall preference score alternative optimization tool (step 5b) (c)	no feasible alternatives	66
Added value (maximum)	54 (b-a)	5 (c-a)

PAS improved the representation of the stakeholders preferences compared to Oracle's current scorecard system due to the use of preference curves.

The three pilot studies show that the PAS can be applied in different organizations, and for different types of problems with a different level of complexity (see Table 5.7). In comparison, the first two pilots were more complex because more stakeholders were involved and more interventions were possible. Applying this approach to multiple context-dependent cases has yield more valuable results than just applying it to one case. PAS is generic, it can be argued based on the results that it can be used for a wide range of real estate portfolio types.

TABLE 5.7 Pilot study comparison on characteristics

Characteristics:	1st pilot study food facilities	2nd pilot study lecture halls	3rd pilot study office location
New or existing case	New	New	Existing
Type of problem	allocation off on campus	allocation of lecture halls on campus	location decision making
CRE strategy	the ambition to create a living campus is to maximize the function of the campus as a place to meet each other and work together	fit changing educational demand	the new location (hub) needs to attract millennials and be attractive to native English speakers
# Stakeholders	6	6	2
# Decision variables	17	28	22
# Design constraints	6	5	4
# Interventions	5	11	1
# Objects	14	18	32

TOC