Post-pandemic Office Real Estate

A pilot study of using scenario planning to develop scenarios with quantitative office space demand for corporate real estate

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Preface

This report marks the final result of my graduation project, which is carried out for the Master Program of Architecture, Urbanism and Building Science, track Management in the Built Environment, at Faculty of Architecture and Built Environment, Delft University of Technology.

I am proud to present this report to you. In this research, I was able to explore the topics that interest me the most. I learnt about corporate real estate through office space demand forecasting, I examined the future of post-COVID-19-pandemic through scenario planning, I dealt with numbers through conducting quantitative research, and I dabbled in data science through incorporating coding in my research methods.

This research will not exist without all the supports. First of all, I would like to express my sincere gratitude to my mentors: Dr. Ir. Monique H. Arkestetijn MBA and Dr. Erik Louw. Monique offered a lot of help during the phase I was lost in my thesis, she has also kept me sharp with her constructive and visionary ideas. Erik helped me realise the importance of being as accurate as possible in academic writing. I learnt how to think critically and get to the point from both of them.

Secondly, I would like to thank my colleagues, supervisor and manager during my internship at Royal Philips. Especially Alette van Haren and Henriette Weiss, thank you for all your instructions and support, you are the greatest people I have worked with. I'd also like to thank all colleagues who have offered help during my internship and thesis process. Thank you all for giving me the opportunity to intern at Philips and adopt Philps Center as the pilot case of my study. I learnt so much in those six months of a full-time internship.

On a personal note, I would like to thank all my friends: Tim, Maita, Danica, Johnny, Serafeim, Chang, Akshit, Weiyu, Zixuan, Gang, Jingwen, David, Ashley, Ehsan, Fabra, Manuela, Alejandro, Gaby, Carlos, Max, Jamila, Alice, Pritha, Daniela, Zisis, Jamie, and so so many others. Thank you for making my life amazing in the Netherlands and supporting me physically and/or virtually in this crazy time. Lastly, I would like to express my deepest love to my mom and my grandparents. Thank you for your unconditional love, support and acceptance.

路曼曼其修遠兮，吾將上下而求索。

The way was long, and distant far was my goal; I would ascend and descend, pursuing my search.

Ziyao Cheng 程子耀
Rotterdam, January 2022

Abstract

The influence of the COVID-19 pandemic is profound and enduring to the entire world. A 'recovery' to go back in time is unlikely to happen due to the lack of uncertainty in the future. The darkest time will eventually pass, whereas post-pandemic, the era in which the pandemic is perceived to have subsided, can still accelerate existing trends and bring up new uncertainties, such as hybrid working, activity-based working and smart building, to the office real estate sector. Corporate Real Estate (CRE), as real property, is owned and/or leased by organisations for their business activities. While office real estate is facing profound structural changes, the CRE department of organisations needs to evaluate their office status quo and reimagine their office of the future.

Scenario planning can act as a valuable tool to help decision-makers evaluate strategies, and office space demand forecast is one of the important indexes that CRE takes into account. Forecasting office space demand by using scenario planning techniques is recommended when the predictability of the external strategic environment is low and the reliability of the organisation's internal data required for forecasting is high as is the case in this post-pandemic era. This research aims to propose a scenario planning methodology that can be applied to develop scenarios with quantitative office space demands at a corporate level. Such methodology and detailed scenarios are valuable for CRE decision-makers to evaluate their strategy regarding post-pandemic office real estate.

This study is developed by operations research. A proper methodology is proposed through the literature study. A pilot study is then taken to apply this methodology to a real-world example. The chosen pilot is the global headquarter of Philips: Philips Center in Amsterdam. In the pilot study, semi-structured interviews and data analytics of an existing survey are conducted, scenarios are developed by following the steps of the proposed methodology. An expert panel was held to help evaluate the replicability and validities of the findings.

Embedded mixed methods research is used for this thesis. Qualitative and quantitative data are both analysed through literature study, semi-structured interviews, and an expert panel. A large chunk of quantitative data analysis including using the programming language approach is conducted during survey data analysis.

The findings of this research provide CRE with a methodology to develop scenarios with quantitative office space demand. By applying this methodology, the output of post-pandemic office real estate scenarios with corresponding quantitative office space demand can be used by CRE decision-makers to evaluate their business strategies.

Keywords:

Scenario planning, Office space demand forecast, Corporate real estate, Office real estate, Office workplace, Hybrid working, Activity-based working, Post-pandemic, COVID-19

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Glossary

Scenario planning
A disciplined method for imaging possible futures in which organizational decisions may be played out. *Scenario planning* results in *scenarios* that are neither *forecasts* in terms of a relatively unsurprised prediction, nor visions that describe the desired future, but the vivid descriptions of plausible futures.

Activity-based working
A working mode in which office users share work-settings and choose to work in different work-settings based on their tasks. In an activity-based working environment, employees have no personal work-settings, they choose freely between several work-settings based on their specific tasks, and these work-settings are shared by employees – employees do not have their own desks.

Hybrid working
A working mode in which employees partly working in the office (on-site) and partly working remotely, such as from home, a café, or any location as long as it's not in the assigned office.

Smart building solutions
Smart building solutions is technology that is implemented in the workplace to help with health & well-being service, sustainability control, strategic space management, etc.

Key indicator
In scenario planning, key indicators are impacted by possible future trends. Key indicators are the descriptions of the scenarios. In each scenario, a set of key indicators are defined. In this thesis, the key indicators are the same as independent variables.

Independent variable
A formula consists of certain independent variables on one side of the equation and a dependent variable on the other side of the equation. In the proposed office space demand forecasting formula, independent variables calculate the dependent variable - total office space demand.

Bandwidth
The bandwidths of independent variables (key indicators) represent the value ranges of these independent variables among all scenarios. A set of values are assigned to each scenarios from the bandwidths.

Work-setting
Work-setting is defined as a workspace where an employee conducts her/his/their work. For example, a work-setting can be an individual workstation, a touch-down desk, a focus room, a phone booth, etc.

Seat count
The seat count in this thesis means individual workplace desk count. It does not include the seats in collaboration space, meeting rooms, etc.

Desk occupancy rate
The ratio of the number of desks that are occupied by users to the total amount of desks.

Share-ratio
The ratio of the number of employees to the number of seats (share-ratio = employee headcount / seat count).

Employment structure
In this thesis, employees are categorised twice as task groups and persona groups. There are four task groups and four persona groups which theoratically lead to 16 types of employees. This classification shapes the employment structure.

Task group
Task groups categorise employees by their tasks, in other words, their ways of working. Each task group has a unique way of working, and this is reflected by the characteristics of their working settings.

Persona group
Persona groups categorise employees by their individual needs in terms of time spent on individual work-settings. To each persona group, a share-ratio of 'employee/seat' is assigned. The 'seats' include the seats of individual desks, such as the desks in open work-settings, focus rooms and touch down work-settings

Abbreviations:

ABW	Activity-based working
CIA	Cross-impact analysis
CoE	Center of Excellence
CRE	Corporate Real Estate
EMEA	Europe, Middle East and Africa
ExCo	Executive Committee
FoW	Future of Work
HR	Human Resources
ICT	Information and communications technology
IFS	Interactive future simulation
INTERAX	Interactive cross-impact simulation
SAS	Space analysis sheet
WFH	Work(ing) from home

1 Introduction

1.1 Problem statement

As of March 2020, the World Health Organization has declared COVID-19 as a global pandemic (World Health Organization (WHO), 2020). The world has been forced to ready itself for the worst global economic fallout since the Great Depression (Georgieva, 2020). Over 170 countries have experienced negative economic growth in 2020, of which the Netherlands has experienced 3,7% fall of GDP in 2020 (Financial Times, 2020; Georgieva, 2020; Wikipedia, 2021a).

The world has made progress in handling COVID-19, yet recovering from the pandemic does not necessarily mean the post-pandemic world will be the same as the pre-pandemic one. Proactive actions have been taken such as conducting massive vaccination campaigns and reopening borders, and economic prediction looks promising: GDP in the Netherlands is expected to have grown by 3,0% in 2021, 3,7% by 2022, and 1,9% by 2023 (De Nederlandsche Bank, 2021; Our World in Data, 2021; RIVM, 2021). As it may seem that COVID-19 will be conquered at one point, it is notable that the influence of COVID-19 will last a much longer time and create structural changes to the world. Similar to the normalisation of strict boarding security checks in airports after 9/11, the society as a whole needs to eventually adapt to the 'new norm' in the post-pandemic world – an era when the pandemic itself is perceived to have subsided (WHO, 2010).

The pandemic also brought structural changes to the corporate real estate (CRE) sector: after experiencing working from home (WFH), many organisations and employees have grown a high acceptance towards hybrid working – partly working in the office and partly working elsewhere (Cushman & Wakefield, 2020b; Hoekjen & Hoekstra, 2021; JLL, 2021a; Jongen et al., 2021). Hybrid working, together with the existing trend of activity-based working (ABW) which allows employees to change different workplaces for different activities, will result in different and less demand for office space area while still achieving productivity and employees satisfaction (ARUP, 2020; Harris, 2015; Pajević, 2021; Verwimp et al., 2021).

However, whether and how much CRE office demand can shrink is dependent on to what extend the hybrid working and ABW amongst others are implemented in the organisations. This leads to an unknown future for the CRE, and one must think about and prepare for it. Demand forecasting serves as the front end of any portfolio management effort (O'Mara, 2000), O'Mara (2000) suggested using scenario planning as the forecasting method when the predictability of the external strategic environment is low and the reliability of the organisation's internal data that is required for forecasting is high as is the case in this post-pandemic era.

Nevertheless, no comprehensive scenario planning methodology that develops scenarios with quantitative descriptions for CRE regarding office space demand is available. Most scenario outputs are usually qualitative when developed by methodologies under the Intuitive Logics (IL) school, and these methodologies do not explain how to develop scenarios

with quantitative details (Bradfield et al., 2005; Meissner & Wulf, 2015). Methodologies with quantitative approaches focus on probabilistic occurrences but do not necessarily generate scenarios with quantitative descriptions, such as methodologies under the Probabilistic Modified Trends (PMT) school (Bradfield et al., 2005; Meissner & Wulf, 2015). In other domains than CRE, scenarios with quantitative descriptions have been developed by integrating mathematical models in the methodologies, yet they do not focus on office space demand specifically (Hafezi et al., 2021; Rezaei et al., 2020). Studies that develop quantitative office space scenarios exist (Cushman & Wakefield, 2020a; EIB (Economisch Instituut voor de Bouw, 2011), however, they focus on regional scales and require large amounts of data that are not applicable for organisations.

This research aims to bridge this gap and develop a scenario planning methodology that produces quantitative scenario outputs for CRE by incorporating an office space demand forecasting model into a scenario planning methodology. A simple conceptual framework of this research is then drawn as figure 1.1.1.

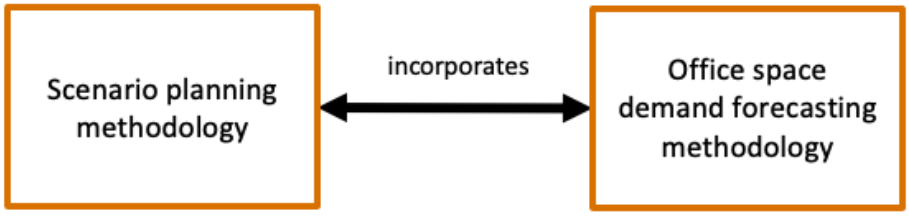


Figure 1.1.1 Conceptual framework (Own illustration)

1.2 Research goal and objectives

This research aims to provide CRE decision-makers with a scenario planning methodology that can be applied to develop scenarios with quantitative descriptions of office space demand at a property or organisational level. Achieving this goal can fill in the research gap of no available methodology existing in this context in the academic domain.

Research objectives are formulated as follows to achieve the research goal:

- Proposing a scenario planning methodology that develops scenarios with quantitative outputs regarding office space demand estimates
- Assessing possible future trends that impact office real estate in the context of post-pandemic, through which customises the methodology to make it applicable for post-pandemic office CRE
- Applying the proposed methodology by conducting a pilot study
- Evaluating the replicability and validity of the methodology and proposing further research to improve the methodology

1.3 Societal and scientific relevance

Scientific relevance

It is found that using scenario planning techniques to develop quantitatively descriptive scenarios is possible (Amer et al., 2013; Hafezi et al., 2021; Pillkahn, 2008; Rezaei et al., 2020). However, there are only limited scientific papers and commercial reports in the field of the real estate industry that used scenario planning to develop scenarios with quantitative estimates of office space demand, and the ones that have done so developed office demand scenarios in wide scope - the methodology does not apply to the scope of a property or an organisation (Cushman & Wakefield, 2020a; EIB, 2011). Research that reveals a holistic set of scenario planning steps to develop scenarios with quantitative details is also limited (Amer et al., 2013; Bradfield et al., 2005; Meissner & Wulf, 2015).

Therefore, a preliminary research gap is identified: there are few scientific papers (or commercial reports) that have proposed comprehensive scenario planning methodologies that can be applied to develop scenarios with corresponding quantitative office space demand at a corporate level. Such a methodology is expected to be proposed in this research.

Social relevance

In terms of societal relevance, this thesis addresses an urgent concern of what will happen to the office real estate sector in the post-pandemic era. While CRE has been experiencing major changes in terms of their workplace, it is valuable to research which trends will accelerate, which trends will fade out, and which uncertainties will emerge. Scenario planning is suggested as an appropriate tool of CRE demand forecasting when the predictability of the external strategic environment is low and the reliability of the organisation's internal data required for forecasting is high (O'Mara, 2000), and CRE in the post-pandemic era can exactly fit into this context.

As the future is unpredictable, developing office real estate demand scenarios helps CRE to understand the future. The research examined possible future trends of activity-based working, hybrid working, smart building, etc, and then analysed all the trends in the framework of scenario planning. Scenarios with corresponding office space demand estimates are developed by following the proposed methodology. Such findings can be examined by CRE decision-makers to evaluate their strategies, thus managing and facilitating their CRE to make it more resilient in the future.

2 Research methodology

This chapter introduces the research methodology. Research questions are introduced in section 2.1. By identifying this research being operations research and positioning the research in the design science research cycle, the research scope is defined in section 2.2. In section 2.3, the research design is established by following the design process illustrated by Binnekamp (2012) and proposed research questions. In section 2.4, specific research methods are indicated along with the explanations regarding why they are chosen. Section 2.5 indicated the data storage plan and ethical considerations.

2.1 Research questions

For this thesis, the main research question and the research sub-questions are listed as follows:

Main research question:

How can scenario planning give quantitative outputs on post-pandemic office space demand for corporate real estate?

Below are the sub-questions:

Sub-RQ1: What is a suitable methodology of scenario planning that can develop quantitative office space demand scenarios on the corporate level?

Sub-RQ2: What is a suitable mathematical formula of office space demand forecasting for corporate real estate in the post-pandemic context?

Sub-RQ3: How can the proposed scenario planning methodology and office space demand forecasting formula be applied for corporate real estate?

2.2 Research scope

As indicated in section 1.2 'research goal and objectives', this research aims to develop a tool of scenario planning methodology that does not yet exist in the specific context and ultimately contribute to the CRE decision-making process. The main research question is formulated as a 'how can' question to design this tool of scenario planning methodology. Based on Binnekamp's (2012) definition, operations research is about solving managerial problems, and it relates to a design problem that fits itself in a design process. Operations research is about designing 'new artefacts (material or immaterial) that do not yet exist', whereas empirical research is about producing knowledge and formulating explanations (Barendse et al., 2012). Therefore, this research is **operations research** that fits into a design process.

The ***Design Science Research Cycles*** by Hevner (2007) is used to understand how this research positions itself in design science and connects to the certain application domain and knowledge base. The goal of the *Design Science Research*, the centre pillar, is to develop or build theories or artefacts – namely a scenario planning methodology in this research. The ***Design Cycle*** concerns developing the methodology and evaluating the methodology – by applying it to a case and evaluating its replicability and validity. The ***Relevance Cycle*** is intersected by *Application Domain* and *Design Science Researc*h – the design of methodology is for the environment where the CRE sector facing uncertain future office demand in the unpredictable post-pandemic era. The ***Rigor Cycle*** bridges the design with *Knowledge Base* by adopting scientific methods and in return contributing to the knowledge base – the design of methodology is developed based on existing knowledge, its completion also fills in the scientific research gap.

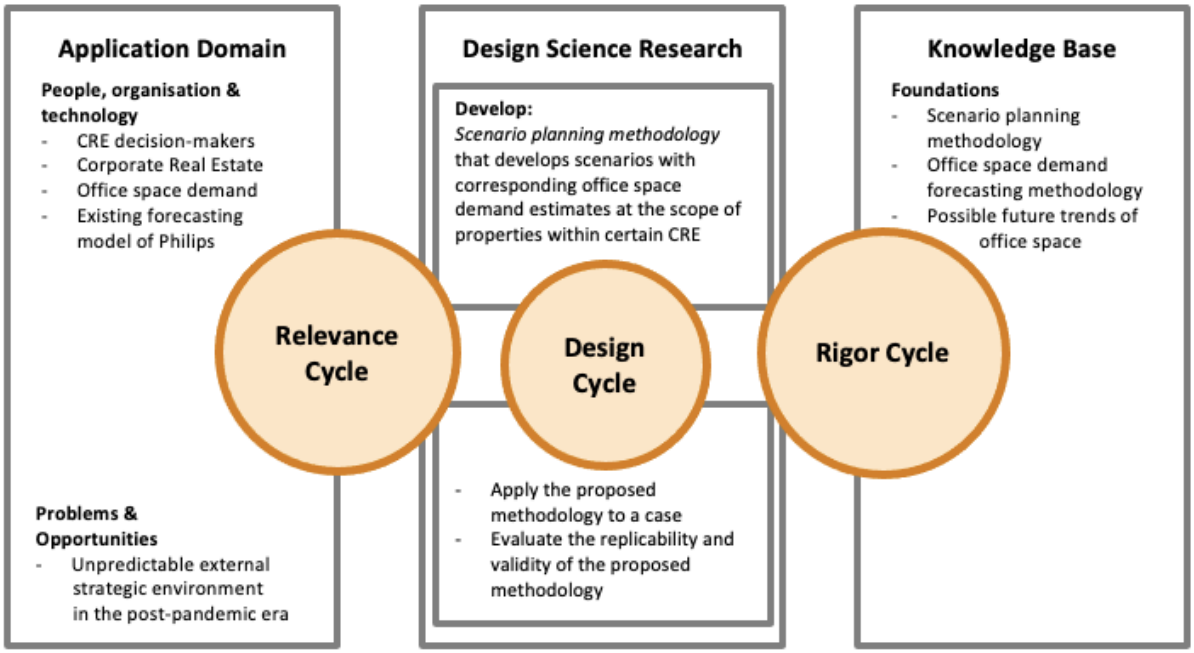


Figure 2.2.1 Design Science Research Cycles (Own illustration, based on Hevner, 2017)

2.3 Research methods design

This section explains how the research methods are designed. As identified in section 2.2, this research is operations research. Operations research should follow the design process as it relates to a design problem (Barendse et al., 2012). Barendse et al., (2012) indicates the design process in formal sciences as the outer cycle in Figure 2.3.1. Operations research is part of the formal sciences (Barendse et al., 2012), thus the research design should follow the indicated design process (the outer cycle in Figure 2.3.1).

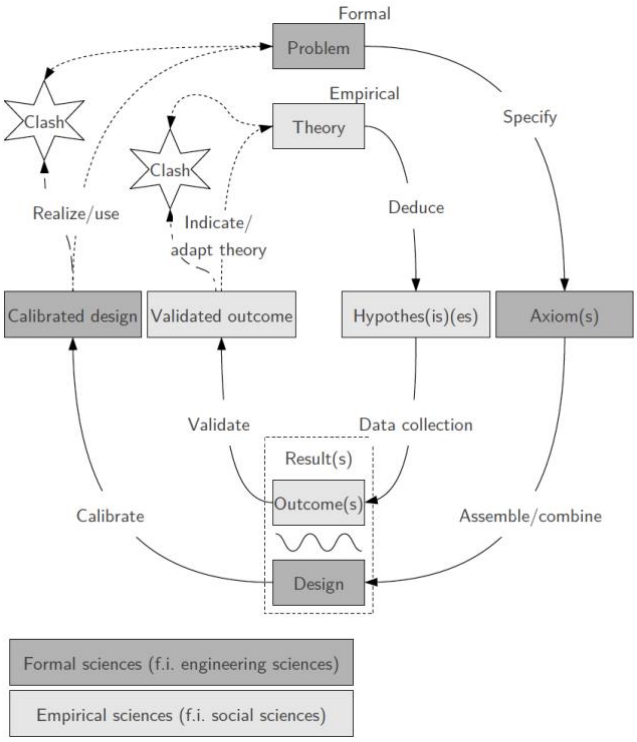


Figure 2.3.1 Formal sciences and empirical sciences process (Barendse et al., 2012)

By comparing the 'design process' in Figure 2.3.1 and the design science research cycle in Figure 2.2.1, it can be identified that the 'design process' (the outer cycle in Figure 2.3.1) is the 'design cycle' in the middle of Figure 2.2.1. The 'design process' shows the patterns that this research design should follow, the design science research cycle shows how the research design is related to the application domain and knowledge base.

Research design is also 'a framework for the generation of evidence that is chosen to answer the research question(s) in which the investigator is interested' (Bryman, 2016, p. 39). Therefore, proposed research methods in the research design are supposed to be the tools to answer research questions.

Sub-question 1 is answered by the literature study on scenario planning. In the design process illustrated in figure 2.3.1, sub-question 1 is about *specifying axioms and developing the (preliminary) design.* The axioms in this research are existing scenario planning methodologies, and the preliminary design is the answer to sub-question 1: a scenario planning methodology. This methodology explains how an office space demand forecasting model can be incorporated in the scenario planning process, the demand forecasting model is not specified yet, hence the design of the proposed methodology needs to be calibrated.

Sub-question 2 is answered by the literature study on office space demand forecasting methodology and possible future trends of CRE office workplace. In the design process illustrated in figure 2.3.1, sub-question 2 is about *calibrating the design* (proposed methodology). An office space demand forecasting model is firstly proposed by the literature study on office space demand forecasting methodology. To fit this model into the context of the post-pandemic CRE office workplace, possible future trends are examined because they

may further specify the independent variables in the model. By answering sub-question 2, a holistic office space demand forecasting formula is proposed. This formula is suitable for the context of post-pandemic CRE office space demand. By incorporating this formula into the proposed scenario planning methodology in sub-question 1, a calibrated (detailed) design of scenario planning is proposed.

Sub-question 3 is answered by applying the proposed scenario planning methodology via a pilot study. In the design process illustrated in figure 2.3.1, sub-question 3 is about *realising/using the calibrated design to solve the problem*. The pilot study should be conducted by following the steps of the proposed scenario planning methodology, thus *research approaches in the pilot study can only be designed after answering the first two sub RQs.*

As illustrated in figure 2.3.1, the iteration of the design process cycle can be run multiple times until there is no 'clash' between the design and the problem. The cycle is only run once in the pilot study, hence the clash might exist. To evaluate the proposed scenario planning methodology, an expert panel is held; to evaluate the proposed office space demand forecasting formula, an interview to understand an existing office space demand forecasting formula (PACT model) is taken.

The research design is illustrated in figure 2.3.2. It is built upon the completion of the literature study in chapters 3 and 4. Research methods and expected outputs are indicated in the right column, the arrows show how are the ***research methods and output*** comply with the ***research questions***.

Embedded mixed methods research is used in this thesis. As stated by Bryman (2016, p. 640), the need for embedded research can arise when quantitative (or qualitative) research needs to be enhanced by qualitative (or quantitative) research. The literature studies examine qualitative and quantitative data. Within the pilot study, qualitative initial scenarios are developed based on the previous literature study on possible future trends and semi-structured interviews. Quantitative data from an existing survey is analysed and the output is enhanced by interviews and the previous literature study to develop quantitative detailed scenarios. Quantitative research is the priority in this thesis, and qualitative research is used to facilitate quantitative research.

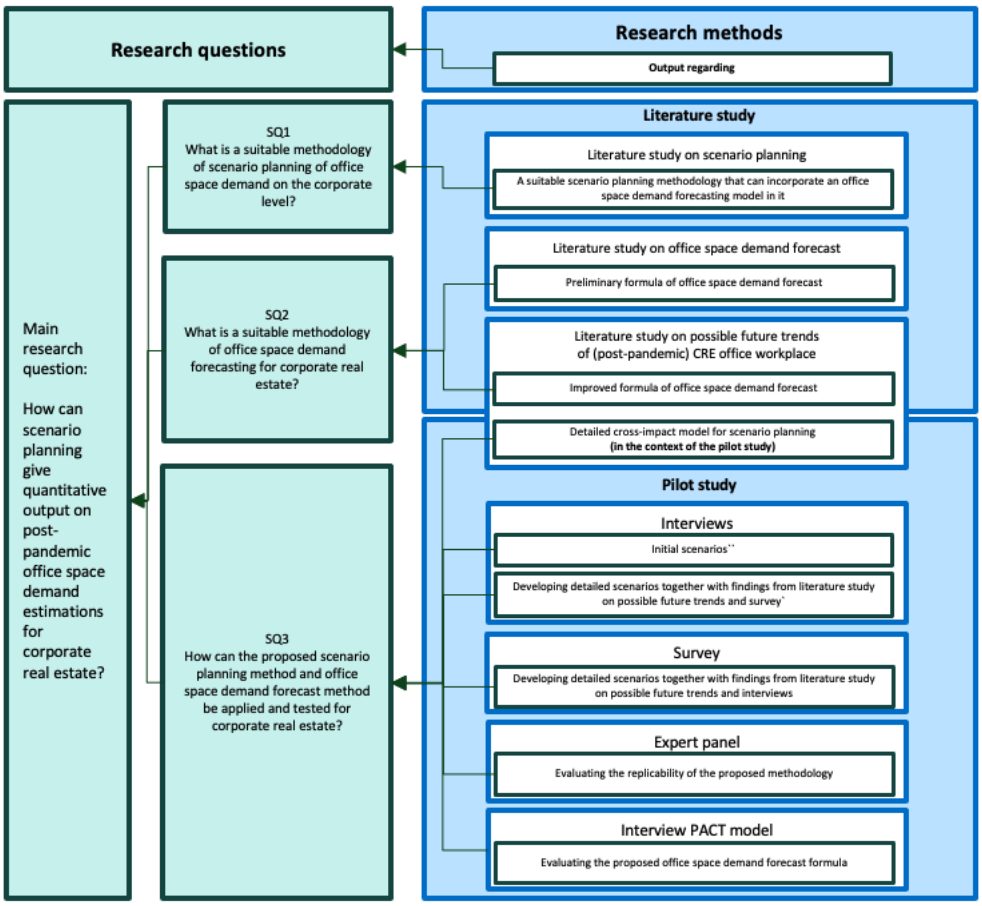


Figure 2.3.2 Research design (Own illustration)

The following two subsections explain why these research methods are chosen to conduct this research, namely literature study and pilot study. It also further explains why the specific research methods in the pilot study are chosen, namely semi-structured interviews, data analysis of the survey, and expert panel.

2.3.1 Literature study

The literature study aims to 'establish what is already known about the topic' and thus to justify the research (Bryman, 2016). In this research, literature study is firstly used to identify the research gap: there is no scenario planning methodology available for developing quantitative office space demand scenarios at corporate levels. Further literature study then focuses on proposing this methodology.

Literature study on scenario planning

To establish what is already known about the scenario planning topic, this set of literature study is finished in chapter 3. Firstly, to identify the research gap, the need of adopting scenario planning for CRE demand forecasting is elaborated, and existing scenario planning methodologies are examined. Secondly, examining existing methodologies is also to propose

a scenario planning methodology. The examination of the methodologies focused on two aspects: (1) examining existing scenario planning methodologies; (2) examining scientific papers that developed scenarios by applying *quantitative* scenario planning methodology. ***Sub-question 1*** is answered.

Literature study on office space demand forecasting methodology

This part of the literature study examines existing office space demand forecasting methodologies. A preliminary office space demand forecasting model is proposed in the form of a formula. This model can be incorporated into the proposed scenario planning methodology.

Literature study on possible future trends of CRE office workplace

The proposed methodology is intended to be applicable for the corporate level, and this research intends to apply the proposed methodology in the post-pandemic context. The literature study on possible future trends of CRE office workplace is conducted to further improve the office space demand forecasting model to make it fit into the post-pandemic CRE office workplace context. After this literature study, an improved office space demand forecast methodology in the form of a formula is proposed, ***sub-question 2*** is answered.

2.3.2 Pilot study

Proposing the comprehensive scenario planning methodology that incorporates the proposed office space demand forecasting model means that the detailed design of the methodology is constructed. In the design process illustrated in figure 2.3.1, the calibrated (detailed) design should be realised/used to solve the problem (Barendse et al., 2012). ***Therefore, the proposed methodology should be applied. This is to answer sub-question 3 and also comply with the design process of operations research.***

This research aims to provide a scenario planning methodology, it is logical to examine whether this methodology works. Van Teijlingen & Hundley (2001) indicated that conducting a pilot study can give indications about whether the proposed method or instrument is appropriate or not. 'Pilot study' refers to two different ways in the social science research (Van Teijlingen & Hundley, 2001). In this research, the pilot study means the 'pre-testing' of a particular research instrument. Therefore, using a pilot study to test out this proposed methodology can assess its adequacy and feasibility (Van Teijlingen & Hundley, 2001). Therefore, a pilot study is adopted for this research.

Pilot selection

In the context of this research, the research findings of the chosen pilot case do not need to and should not be generalised to a wider scope. This is not only because the pilot study might reveal the limitations of the research instrument (proposed scenario planning methodology) (Van Teijlingen & Hundley, 2001), but also because scenario outputs are supposed to be different in different contexts.

To select a pilot study case, Yin's (2009) distinguishment of five types of cases is used. The case study research is 'concerned with the complexity and particular nature of the case', it includes research on a single organisation (Bryman, 2016, p.60). Although 'pilot study' is different from 'case study', the pilot study in this thesis is a research on the CRE of an organisation, which can be considered as a 'case'. Therefore, Yin's (2009) distinguishment of the cases is used to help the researcher to understand what characteristics should the pilot case possesses. Yin (2009) distinguished the cases as the *critical* case, the *extreme* or *unique* case, the *representative* or *typical* case, the *revelatory* case, and the *longitudinal* case. Whether the case is appropriate for the research depends on how fairly does the case meet the research design criteria of reliability, replicability, and validity (Bryman, 2016; Yin, 2009). Therefore, a ***representative*** or ***typical*** case should be chosen as the pilot study case, as they are not extreme or unusual in certain ways, they can epitomise a broader category of cases, and/or they can provide a suitable context for answering certain research questions (Bryman, 2016).

The author joined Royal Philips as a full-time intern from April to October 2021 in Philips Real Estate Function, Strategy, Mergers & Acquisitions, and Innovation (SMAI) Team. The job content is mainly regarding data analysis of the ***Future of Work*** (FoW) survey that Philips is doing in-house. After consideration, Philips Center in Amsterdam is chosen to be the pilot for this research.

The reasons are:

- ***The pilot study case is representative and typical***
  The proposed methodology is designed for CRE office demand forecasting. The pilot Philips Center is a typical office property of CRE. Yin (2009, p.48) defines that, with a representative and or typical case, 'the objective is to capture the circumstances and conditions of an everyday or commonplace situation. The chosen pilot study case suits this description. It is also one of the 'top 60' properties in Philips as it has a relatively large population and is crucial in Philips' future strategic plan. While the center of excellence (CoE) of Philips Real Estate are mostly based in the EMEA (Europe, Middle East and Africa) region, especially the Netherlands, these specialists are familiar with the context of Dutch CRE, workplace and Philips Center per se. Hence the data required from interviews with relevant stakeholders can be highly valid.
- ***The pilot's internal data required for forecasting has high reliability.***
  O'Mara (2000) indicated that scenario planning is an appropriate CRE demand forecasting method when the predictability of the external strategic environment is *low*, and the reliability of internal data required for forecasting is *high*. While the pandemic provides the former, the latter can be provided by the available FoW survey, access to interviews with internal stakeholders, and access to detailed information regarding personnel and the building, etc.
- ***The pilot is facing the decision of 'relocating or staying'***
  O'Mara (2000) indicated that the appropriate strategic context of conducting scenario planning is 'Repositioning/Growth management'. This suits exactly the situation of the pilot.

Below indicates the research methods that are taken in the pilot study. These research methods are taken to conduct the steps of the proposed scenario planning methodology.

Several steps of the proposed methodology are conducted in the literature study on possible future trends of CRE office workplace, this is explained at the beginning of section 4.2. Therefore, the research methods in the pilot study should finish the rest of the steps.

Semi-structured interviews

To ***develop initial scenarios*** and provide input to ***project bandwidths and prepare office space demand forecasts***, interviews are conducted in the pilot study. Interviewees are CoEs and important stakeholders in Philips Real Estate. Their job content is either highly relevant to FoW research, or highly relevant to CRE strategy regarding Philips's office. Interviewees' background varies from CRE experts regarding strategy planning, merges & acquisitions, facility management, to workplace solution experts, data analyst.

One-on-one semi-structured interviews are conducted, open questions regarding the impact of trends identified in the CIA model are used to provide qualitative data to develop initial scenarios. Some fixed (close-ended) together with open questions are also asked to some interviewees to evaluate and propose bandwidths of key indicators. Quantitative data from interviewees' experience and knowledge is evaluated together with quantitative data from the literature study and data analytics of the survey. The bandwidths of key indicators are then identified, and certain values of bandwidths are assigned to initial scenarios. Detailed scenarios are then developed.

Data analysis of FoW Survey

To finish the steps of projecting bandwidths of key indicators and preparing office space demand forecasts, quantitative data is needed. Self-administered questionnaires (surveys) and corresponding quantitative data analysis are commonly used in the quantitative research (Bryman, 2016). Conducting proper data analysis of a proper survey helps the researcher to finish the mentioned steps of the proposed methodology. It is then adopted as a research method in the pilot study.

An existing survey was taken in Philips Center called FoW survey. As an important part of FoW research, the FoW survey is sent to employees to assess how the pandemic impacts Philips real estate footprint and to investigate employees' perceptions of work mode in the future (Jansen et al., 2021).

The survey is attached in Appendix B. Employees who are assigned to Philips Center filled in the survey in October 2020. After reviewing the survey, the date of the survey is considered recent enough to be valuable for this thesis, and the dataset is sufficient for data analysis to provide the required output. As of the time when the survey was conducted, there were 1646 employees assigned to Philips Center. There were 590 respondents, yielding a response rate of 36%, which is above the 30% threshold that is needed to achieve significant conclusions (Jansen et al., 2021).

The data analysis of the survey is finished through RStudio by R language. R is a programming language for statistical computing and graphics. RStudio is an integrated development environment for R (Wikipedia, 2021d). It is widely used among statisticians and data miners

for developing statistical software and data analysis (Wikipedia, 2021c). Analysing survey data is part of the author's job content, the code used for data analysis in the internship is examined and modified specifically for this thesis.

Expert panel and Interview PACT model

The expert panel is conducted after the application of the methodology to help evaluate (1) the ***replicability*** and ***external validity*** of the proposed scenario planning methodology of scenario planning, (2) the ***internal validity*** and ***measurement validity*** of research findings regarding initial and detailed scenarios.

Replicability means the ability to replicate research findings to others, and ***external validity*** is concerned with the question of 'whether the results of a study can be generalised beyond the specific context' (Bryman, 2016, p. 42). As scenarios are different in different scopes by nature, the findings regarding scenario outputs do not have replicability and external validity. However, the proposed methodology that combines scenario planning and office space demand forecast may have replicability and external validity – this means that the same methodology may be applied in another context.

Internal validity is concerned with the question of whether the causal relationship between two variables is reasonable, and ***measurement validity*** is to do with the question of 'whether a measure that is devised for a concept does reflect the concept that it is supposed to be denoting' (Bryman, 2016, p. 41). These two validities are crucial to be evaluated for the research findings regarding the initial and detailed scenarios: the causality of the CIA model needs to be evaluated to see if it is complete and reasonable, and the data analytics of the survey and the survey questions needs to be evaluated to see if they reflect the real case.

Interview PACT model

The interview is conducted to understand an existing office space demand forecasting model, namely PACT model. PACT model is an office space calculation tool developed by the Center for People and Buildings (CfPB). It has been 'developed, adapted and tested while being applied in several cases in for-profit and non-for-profit companies' (Bruyne & Beijer, 2015, p. 125). After comparing the PACT model and the proposed office space demand forecasting formula in this thesis, the proposed formula can be evaluated in terms of its shortcomings and potential improvement. This is also to examine the ***external validity*** of the research.

2.4 Data storage plan and ethical consideration

Good data management and stewardship is a prerequisite that supports knowledge discovery and innovation. All data collected and produced will be stored at the proper place, as well as all working results of this thesis.

An embargo agreement has been signed to ensure all confidential information to be stored in a separate (confidential) part of the thesis/report that will never become public and will

only be stored by the Board of Examiners for use by accreditation. In this thesis, Chapters 5 and 6 will be regarded as confidential parts. The raw data acquired from Philips will be protected at a required confidentiality level requested by TU Delft and Philips.

Raw data includes interviews with stakeholders within Philips and the survey data. All interviewees have signed the interview consent form before participating in the interviews. Their personal information will not be shared in this thesis, and quotes from interviews will not reveal traces that can be used to indicate the identity of interviewees. The survey is anonymous, no personal information of the participated employees can be identified in the thesis. Additional documents provided by Philips and the author's internship content details are also part of raw data, they are partly used in the case study chapter and this chapter will not be shared with the public.

3 Scenario planning

This chapter answers sub-question 1: What is a suitable methodology of scenario planning of office space demand on the corporate level? In the design process cycle, answering sub-question 1 is to specify axioms and develop the preliminary design.

To answer this sub-question, the first thing that needs to be clarified is why such methodology needs to be proposed. Section 3.1 firstly explains the term scenario planning, and the need of adopting scenario planning for CRE demand forecasting is then explained. Section 3.2 then section existing scenario planning methodologies and their practices. It is identified in section 3.2 that such methodology does not yet exist. Therefore, the research gap of this thesis is identified, thus the reason why such methodology needs to be proposed is justified. In section 3.3, a suitable methodology is proposed, sub-question 1 is then answered.

3.1 The need for scenario planning

This section explains the term scenario planning and the reason why it is appropriate for CRE office space demand in the post-pandemic context.

3.1.1 What is scenario planning

Defined as 'a disciplined method for imaging possible futures in which organizational decisions may be played out' (Schoemaker, 1995), *scenario planning* results in *scenarios* that are neither *forecasts* in terms of a relatively unsurprised prediction, nor visions that describe the desired future, but the 'vivid descriptions of plausible futures' (Lindgren & Bandhold, 2003).

It is important to distinguish the term *scenario* and *strategy*, while the former is 'what might happen', the latter is 'what should we do'. Scenarios are not long-term plans or strategies per se, they form the context for long-term plans instead. Figure 3.1.1 introduces the applicable planning situations for scenarios, from which the relations between scenario and strategy can be identified. While the strategy construction cannot be built solely based on scenarios, the selection and evaluation of existing strategies can be carried out based on scenarios and scenarios-based techniques (Lindgren & Bandhold, 2003).

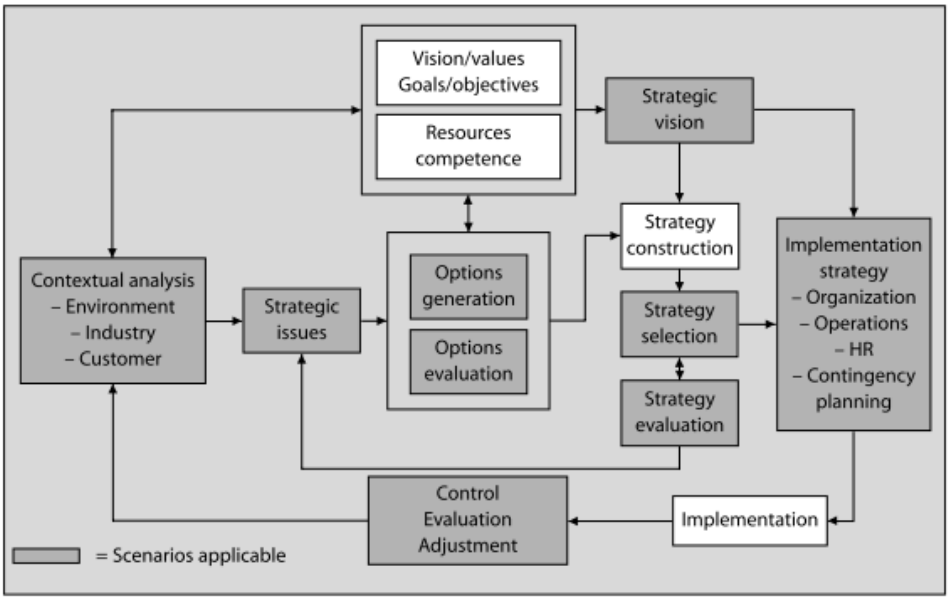


Figure 3.1.1 Different planning situations where scenarios are useful (Lindgren & Bandhold, 2003, p46)

It is also notable that, although scenarios are essentially 'imaginative constructs' and they are usually qualitative and not necessarily quantitative, scenarios would be more valuable if they are also based on quantitative arguments and expressed in quantitative ways (Lindgren & Bandhold, 2003).

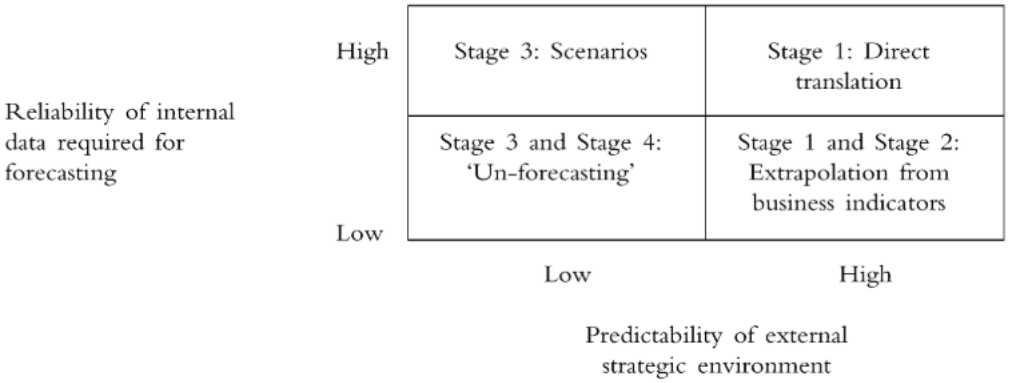
3.1.2 Balancing demand and supply – Four-stage demand forecasting[1] process

O'Mara (2000) described a 'structuring dilemma' in the corporate real estate (CRE) sector, where the need for long-term physical and financial obligations to implement the commitments does not comply with the competitive environment with high turbulence that many companies deal with nowadays. The former can be interpreted as 'supply' whereas the latter 'demand', thus the dilemma, which is at the core of the fundamental challenge of CRE planning (O'Mara, 2000), can then be construed as the mismatch between the supply and demand.

Balancing between the demand and supply by demand forecasting is then beneficial for the future CRE planning (O'Mara, 2000). A four-stage process matrix of demand forecasting is proposed by O'Mara (2000) (Figure 3.1.2), in which four demand forecasting methods are distinguished. O'Mara (2000) identified the reasons for the existence of the dilemma mentioned above as the uncertainty of the external strategic environment for the company and the uncertainty of approaches which the company's CRE decision-making processes decide. These two reasons are interpreted as the two determinants which impede the quantitative forecasting process: the predictability of the external strategic environment, and the reliability of internal data required for forecasting.

[1] It is notable that the 'forecasting' mentioned here by O'Mara (2000) is different from the 'forecast' described above by Lindgren & Bandhold (2003). The 'forecast' defined by Lindgren & Bandhold (2003) is restrained to stage 1 and 2 of the 'four-stage demand forecasting process' proposed by O'Mara (2020). The 'forecasting' of O'Mara (2020) refers to a general process of future planning.

Stage 1: Direct translation from business data
Stage 2: Extrapolation from business indicators
Stage 3: Scenarios
Stage 4: 'Un-forecasting'



Applicable stage	*Appropriate Strategic Context*
1. Direct translation	Migration (baseline for all contexts)
2. Extrapolation	Consolidation
3. Scenarios	Repositioning/Growth management (all contexts to some degree)
4. Un-forecasting	Growth management (all contexts to some degree)

Figure 3.1.2 Stages of demand forecasting and appropriate strategic context for stages (O'Mara, 2000, p. 127 & p. 133)

Since the strategic context of CRE differs in different companies, applicable stages are suggested to apply to various strategic contexts (figure 3.1.2). Defined as a modelling process of 'what if' questions of possible business conditions, scenario planning, stage 3 is suggested to be adopted when the immediate pressure exists to make a long term (3 to 5 years) real estate plan, especially when the strategic context is about repositioning or growth management (O'Mara, 2000). O'Mara (2000) also indicated that conducting scenario planning is appropriate when the predictability of the external strategic environment is low, and the reliability of internal data required for forecasting is high. It is emphasised that, instead of a substitute for stages 1 and 2, stage 3 is the evolution of previous stages as the framing of scenarios relies on the outcome of previous stages (O'Mara, 2000).

Therefore, the need for scenario planning emerges in the situation where organisations have highly reliable internal data required for forecasting while the post-pandemic provides a low predictable external strategic environment. In other words, to investigate post-pandemic CRE office demand and develop quantitative[2] outputs, ***scenario planning*** is the most appropriate approach of demand forecasting.

[2] All stages of demand forecasting identified by O'Mara (2000), including scenario planning, include quantitative forecasting methods and ultimately develop quantitative demands.

3.2 Scenario planning methodologies

After explaining the need of adopting scenario planning to investigate CRE office demand in the last section, this section examines existing scenario planning methodologies and practices in order to identify whether a suitable methodology of office space demand scenario planning on the corporate level exists or not.

The examination of the methodologies focused on two aspects: (1) examining scenario planning methodologies and especially focusing on 'quantitative' scenario planning methodologies (section 3.2.1); (2) examining scientific papers that developed scenarios by applying *quantitative* scenario planning methodology (section 3.2.2).

> The search query of the examination is:
> TITLE-ABS-KEY ("scenario planning" AND quantitative)
>
> 118 documents were found, 2 of which are analyses of existing scenario planning methodologies, 58 of which developed scenarios by scenario planning methodologies with quantitative aspects.
>
> The first 2 papers, and other papers of analysing existing scenario planning methodologies that are found by checking relevant citations are examined first. The other 58 papers that practised 'quantitative' scenario planning are examined secondly.

Later on, existing practices of *office demand* scenario planning by the public organisation and consultancy company are examined in section 3.2.3. Together with the literature review on existing scenario planning methodologies and practices in scientific papers. It is identified that a suitable methodology that can develop quantitative office space demand scenarios on a corporate level does not yet exist. Therefore, the research gap of this thesis is identified at the end of this section.

3.2.1 Existing methodologies

There are two main schools of methodologies for scenario planning that are initiated from Anglophone countries, namely Intuitive Logics (IL) and Probabilistic Modified Trends (PMT), and another main school named *La prospective* which is from France (Meissner & Wulf, 2015). However, as the distinction between IL/PMT *and La prospective* is somewhat blurry, and *La prospective* is more often used for public sector planning (Bradfield et al., 2005), only IL and PMT are presented as a comparison in Table 3.2.1.

Scenario characteristics	**Intuitive Logics approach (IL)**	**Probabilistic modified trends (PMT)**
Purpose	Multiple, from a one-time activity to make sense of situations and developing strategy, to an ongoing learning activity	A onetime activity to make extrapolative prediction and policy evaluation
Scenario type/perspective	Descriptive or normative	Descriptive

Scope	Can be either narrow or broad, ranging from global to a specific issue	Narrow, focusing on the probability and impact of specific events
Time frame	3-20 years	3-20 years
Methodology type	Process orientation - inductive and deductive Essentially subjective and qualitative	Outcome orientation - directed and objective Quantitative and analytical
Tools	Brainstorming, STEEP analysis, and stakeholder analysis, etc.	Trends impact analysis, cross-impact analysis, etc.
Identifying key driving forces	Intuition – STEEP (Societal, Technological, Economical, Environmental and Political) analysis, brainstorming techniques and discussion with experts	Fitting curves to historical time series data to identify trends and use expert judgement to create the database of unprecedented events
Developing scenario set	Defining the scenario logics as organising themes or principles (often in matrices)	Monte Carlo simulations to create an envelope of uncertainty around base forecast of key indicators
Output of scenario exercise	Qualitative - set of equally plausible scenarios in discursive narrative form supported by graphics, there may be some limited quantification. Implications, strategic options and early warning signals are increasingly a part of scenario output.	Quantitative - baseline case plus upper and lower quartiles of adjusted time series forecasts. may be embellished by short storylines.
Probabilities of scenarios	All scenarios are equally plausible.	Conditional probability of occurrence of unprecedented and disruptive future events.
Number of scenarios	Generally 2-4	Often 3-6, based on the number of simulations
Evaluation criteria	All scenarios are equally plausible.	Plausible and verifiable in retrospect

Table 3.2.1 Comparison of principal scenario planning methodologies (Bradfield et al., 2005, p. 807-808)

Intuitive Logics (IL), as one of the most frequently used methods for scenario planning in organisations, is often referred to as the standard methodology for scenario planning (Meissner & Wulf, 2015). IL school believes that business decisions are based on the industry's most crucial and uncertain driving forces, which are a complex set of relationships among economic, political, technological, social, resource and environmental factors (Huss & Honton, 1987; Meissner & Wulf, 2015). These factors form the basis of a 2x2 matrix that frames the scenarios (Meissner & Wulf, 2015). Other than the 2x2 matrix, methodologies from IL school may also use narrative causal chains to develop scenarios in organisations (Meissner & Wulf, 2015). The methodology proposed by Stanford Research Institute International (SRI) is the most frequently used one among all IL variations (Amer et al., 2013; Huss & Honton, 1987).

The effectiveness of IL in terms of assisting an organisation for the future was questioned in the literature, especially its limited ability to deal with the uncertainty arising from extreme and unforeseeable events (Meissner & Wulf, 2015; Rabianski & Gibler, 2007; Wright & Goodwin, 2009). Two other methodologies have been developed to enhance IL, namely *Backwards logic method (BLM) and Antifragile methodology (AF),* the former uses backward logic to build causal links of factors, and the latter refrains from integrating all causal linkages together and moves the level of analysis directly to the organisation's strategy (Derbyshire & Wright, 2014; Meissner & Wulf, 2015; Wright & Goodwin, 2009).

However, It is notable that ***no*** mathematical algorithm is used in methodologies from IL school to develop scenarios (Amer et al., 2013). Methodologies of IL school usually develop qualitative scenarios (Bradfield et al., 2005; Meissner & Wulf, 2015).

Probabilistic Modified Trends (PMT) school includes two quite distinctive matrix-based methodologies, ***Trend Impact Analysis (TIA)*** and ***Cross Impact Analysis (CIA),*** these two methodologies include the probabilistic modification of extrapolated trends (Amer et al., 2013; Huss & Honton, 1987). CIA and TIA have similarities in certain steps, however, CIA has an additional layer of taking the probability of occurrence of prior events affecting the future into account (Amer et al., 2013; Bradfield et al., 2005). It is concluded that CIA methodologies are better approaches to develop a set of alternative scenarios by considering probabilities of events/trends affecting future events/trends through cross-impact calculations (Amer et al., 2013).

Interactive Cross-Impact Simulation (INTERAX) and ***Interactive Future Simulation (IFS)*** are both CIA scenario planning methodologies. The main differences between INTERAX and IFS are: (1) there is no Monte Carlo simulation in IFS - a computational algorithm that relies on repeated random sampling to obtain numerical results, and (2) there is no need for the independent forecast of the key indicators or variables in IFS (Amer et al., 2013; Huss & Honton, 1987).

Generic scenario generation steps	**SRI (IL)**	**The Futures Group (TIA)**	**INTERAX (CIA)**	**Interactive Future Simulations (IFS) (CIA)**
The topic	1. Analysing the decisions and strategic concerns	1. Identifying key scenario drivers 2. Creating scenario space	1. Defining the issue and time period of analysis	1. Defining and structuring the topics
Key decision	2. Identifying the key decision factors		2. Identifying key indicators	
Trend extrapolation		3. Collecting time series data 4. Prepare naïve extrapolation	3.Projecting the key indicators	
Influencing factors	3. Identifying the key environmental factors	5. Establishing list of impacting events	4. Identifying the impacting event	2. Identifying areas of influence
Analysis of factors	4. Analysing the environmental factors	6. Establishing probabilities of events occurring over time	5.Developing event probabilities distribution	3. Defining descriptors; writing essays; assigning initial probabilities
Cross-impact			6. Estimating impacts of events on key indicators 7. Completing cross-impact analysis	4a. Completing cross-impact matrix
Initial scenarios	5. Defining scenario logics	7. Modifying extrapolation	8. Running the model	4b. Running the program 5. Selecting scenarios for further study
Sensitivity analysis				6. Introducing uncertain events; conduct sensitivity analysis

Detailed scenarios	6. Elaborating the scenarios	8. Writing narratives		7a. Preparing forecasts
Implications	7. Analysing implications for key decision factors 8. Analysing implications for decisions and strategies			7b. Studying implications

Table 3.2.2 Comparison of the steps needed in scenario planning approaches (Amer et al., 2013, p.31 & Huss & Honton, 1987, p. 21)

A comparison of the steps of different methodologies is presented in table 3.2.2. It is found that the 'quantitative' scenario planning methodologies develop scenarios with (quantitative) probabilistic occurrences but not quantitative descriptions in terms of 'quantitatively described scenarios'.

As this thesis aims to propose a methodology that develops scenarios with quantitative description – office space demand scenarios which are quantitatively described, existing scenario planning methodologies do not explain how such quantitative scenarios can be developed. In the next section, scientific papers that practised scenario planning are examined in order to see how they were able to develop quantitative scenarios.

3.2.2 Scenario planning scientific practices in different domains

Scientific papers that practised quantitative scenario planning methodologies are examined in this section. Quantitative scenario planning methodologies are proposed in many scientific papers and applied to certain domains. The specific methodologies and research approaches differ in different papers due to variable research scopes and domains. After reviewing scientific papers that practised 'quantitative scenario planning', it is found that three kinds of 'quantitative scenario planning' can be differentiated.

The first one is using quantitative research methods, such as surveys and data analytics, in the scenario planning process. Scenarios that are developed while partly using the quantitative method in the process do not necessarily have quantitative descriptions. For examples: Marzban & Mohammadi (2020) conducted an 'importance and uncertainty questionnaire' when developing scenarios of electricity distribution, Ojoyi et al. (2017) conducted surveys to households to develop scenarios of climate variability, and Assumma et al. (2020) adopted quantitative dynamic models to examine dynamic behaviours in scenarios of the resilience of cities and territories. These papers partly adopted quantitative research approaches, yet the scenario outputs are still qualitative and do not come with quantitative descriptions.

The second one is using quantitative modelling to simulate all possible scenarios and/or generate probabilistic scenarios – scenarios with corresponding possibilities of their occurrences. Scenarios developed by quantitative modelling do not necessarily have quantitative descriptions either, while their probabilistic occurrences may be identified. For examples: Alipour et al. (2017) used the Fuzzy Cognitive Map technique to simulate and

identify scenarios for oil production, Vann et al., (2012) developed an approach to integrate conditional simulation model in scenarios planning to develop probabilistic scenarios for mineral projects, and Samejima et al. (2008) found out that there is no difference between scenarios developed by qualitative methods and scenarios generated by their proposed Monte Carlo simulation model when developing business scenarios. Scenarios that are developed by using quantitative modelling are assigned with quantitative probabilities of their occurrences, yet these scenarios do not have quantitative descriptions.

The third one is about scenarios with quantitative descriptions. A mathematical model (formula) is usually developed in the scenario planning process to process and derive quantitative descriptions for scenarios. For example, Hafezi et al. (2021) used a quantitative approach to generate scenarios, they developed a natural gas forecasting model to derive quantitative descriptions for detailed scenarios for global natural gas demand. Rezaei et al. (2020) adopted all three mentioned types (quantitative research methods, quantitative simulation modelling, and mathematical model) and developed qualitatively-quantitatively descriptive scenarios with probabilistic occurrences for gasoil consumption by incorporating quantitative prediction models with scenario planning methodology and conducting comprehensive cross-impact analysis in scenario planning. It is found that, by incorporating a mathematical model into the scenario planning process, scenarios with quantitative descriptions can be developed.

These three types do not contradict and can be applied together, yet only the last one can develop scenarios with quantitative descriptions. Therefore, a suitable scenario planning methodology in this thesis should at least adopt the approach of the last one: ***incorporating a mathematical model into the scenario planning methodology.*** However, to the author's knowledge, no scientific paper has developed quantitative office space demand scenarios. Office space demand scenario planning practices outside the scientific literature need to be examined to see if such methodology exists.

3.2.3 Quantitative office space demand scenario planning practices

Despite quantitative office space demand scenarios have not yet been developed in scientific papers, such scenarios have been developed in practice by Dutch public organisations or in commercial papers by consultancy companies.

Mathematical models were adopted in the process of scenario planning in some research (Cushman & Wakefield, 2020a; EIB, 2011). However, the scope of these practices concerned the office market at a regional level rather than a specific CRE level. Their approaches are not applicable in this thesis.

To elaborate, EIB (2011) performed office space demand forecasts for Utrecht with the time scope of 2020-2040. It first developed the demand forecasting model. The independent variables in the model were assigned with different values in different scenarios, therefore the office demand differed in different scenarios. One baseline scenario and 5 variants with corresponding regional office space demand forecasts were developed. Cushman & Wakefield (2020a) developed probabilistic scenarios with quantitative office demand, office vacancy rate, and office employment amount. By evaluating macroeconomics factors such as

economic growth, population growth and structural impacts of WFH brought by the pandemic, the scenarios for several geographical regions such as Asia Pacific, Europe, etc.

Therefore, the research gap is identified: a suitable scenario planning methodology for office space demand on the corporate level does not yet exist. In order to fill in the gap, a suitable scenario planning methodology needs to be proposed. The next section focuses on proposing a suitable methodology, and sub-question 1 is then answered.

3.3 Proposed scenario planning methodology

To answer sub-question 1: *What is a suitable methodology of scenario planning of office space demand on the corporate level?* A suitable methodology has to be proposed as it has been identified that such a methodology does not yet exist. This methodology is proposed upon literature study on existing scenario planning methodologies and practices.

As indicated in section 3.2, a mathematical model (formula) should be incorporated into the scenario planning methodology. A formula consists of certain independent variables on one side of the equation and a dependent variable (total office space demand in this thesis) on the other side of the equation. In different scenarios, different sets of values of independent variables shall be assigned, thus different dependent variables will be derived in corresponding scenarios.

After examining existing scenario planning methodologies in table 3.3.2, resemblances of 'independent variables' in the to-be-proposed mathematical formula and 'key indicators' in the ***INTERAX*** approach are found. In INTERAX, 'key indicators' are projected first, they are also impacted by possible future trends(events) and therefore differ in different scenarios. While in real life and also in existing practices examined in section 3.2, 'independent variables' in the mathematical formulas are also impacted by the occurrences of future trends (events) (Cushman & Wakefield, 2020a; EIB, 2011). Therefore, it is possible to regard the 'independent variables' as 'key indicators' – in this way, a mathematical formula can be incorporated into scenario planning methodology. The steps of ***INTERAX*** scenario planning approach exactly provide this possibility (Amer et al., 2013; Huss & Honton, 1987).

What's more, scenarios made by ***INTERAX*** approach can assist companies with major decisions including market opportunities, capital structure, and research and development planning and often used in uncertain business environments (Amer et al., 2013; Huss & Honton, 1987). As a tool for strategic management, ***INTERAX*** is also often associated with a corporate forecasting model or financial simulation model (Huss & Honton, 1987).

Therefore, INTERAX is used as the basis to develop a suitable methodology for this thesis. As a similar approach to INTERAX (Amer et al., 2013), IFS is examined together with INTERAX. Both approaches are under PMT school. The steps needed for INTERAX and IFS approach are concluded in Table 3.3.1.

CIA scenario generation steps	INTERAX (Interactive Cross-Impact Simulation)	IFS (Interactive Future Simulations)
The topic	1. Defining the issue and time period of analysis	1. Defining and structuring the topics
Key decision	2. Identifying key indicators	
Trend extrapolation	3. Projecting the key indicators	
Influencing factors	4. Identifying the impacting event	2. Identifying areas of influence
Analysis of factors	5. Developing event probabilities distribution	3. Defining descriptors; writing essays; assigning initial probabilities
Cross-impact	6. Estimating impacts of events on key indicators 7. Completing cross-impact analysis	4a. Completing cross-impact matrix
Initial scenarios	8. Running the model	4b. Running the program 5. Selecting scenarios for further study
Sensitivity analysis		6. Introducing uncertain events; conduct sensitivity analysis
Detailed scenarios		7a. Preparing forecasts
Implications		7b. Studying implications

Table 3.3.1 Comparison of the steps needed in INTERAX and IFS scenario planning approaches (Amer et al., 2013, p.31)

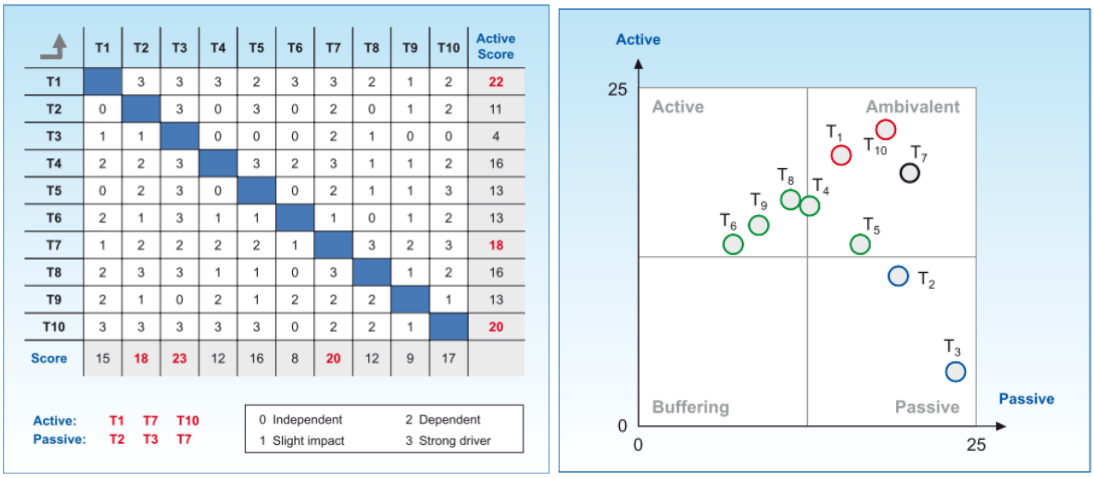
Both INTERAX and IFS start with ***defining the issue*** which includes geographical scope and time period (Huss & Honton, 1987). This beginning is similar to all other scenario planning approaches (Amer et al., 2013; Bradfield et al., 2005; Huss & Honton, 1987). ***Identifying key indicators*** is the next step of INTERAX, and the key indicators in this thesis will be the independent variables in the (office space demand forecast) mathematical formula. This is where the intertwined relationship of scenario planning and demand forecast model lies: the later research on demand forecast indicates required items of *independent variables*. These variables are the *key indicators* of scenario planning.

The first major difference between INTERAX and IFS is their approaches to dealing with key indicators and possible future events (in INTERAX), and descriptors (in IFS). On the one hand, INTERAX explicitly separates possible future events and key indicators in steps 1-6. ***Key indicators*** are defined as '*characteristics of a system which can be measured, counted, or estimated*', this definition is aligned with the definition of independent variables in a mathematical formula. It is suggested in step 3 of INTERAX that the independent forecast of key indicators should be developed via 'econometric and time series techniques or forecasts available from the literature'(Huss & Honton, 1987). While ***possible future events*** are those whose occurrence may significantly affect one or some of the key indicators. The impact estimations are done in steps 4 and 6. The identification of events and their impacts are suggested to be identified through a comprehensive Delphi study, which is not realisable in this thesis due to the limited time and source. On the other hand, IFS mixes up trends, events, key indicators, etc., and defines them as 'descriptors'. IFS suggests that the prior probabilities of the occurrence of these descriptors can be achieved through literature review, conducting interviews, and a Delphi-like approach (Amer et al., 2013; Huss & Honton, 1987). As the key indicators are clear and important for later analysis of office space demand forecast in this thesis, it is considered that INTERAX should still be adopted in this phase, yet the identification of future events and their impact should be conducted through data collection of literature review and interviews instead of Delphi study.

The second major difference is the step of ***analysis of factors,*** which is *step 5* of INTERAX and *step 3* of IFS. The modelling running process of INTERAX are iterations of events affecting each other in each interval of the whole time scope. This causes the output of scenarios to be several continuous forecasted functions – several possible demand functions if applied to this thesis. While the output of IFS will be 'states' scenarios: 'descriptions of a business environment as it would occur at the end of the forecast horizon (Huss & Honton, 1987)'. As for this thesis, the desired output is CRE office scenarios with quantitative office space demand at the era of post-pandemic: when the COVID-19 pandemic has been considered to have subsided. This indicates that dividing forecast time horizons is not applicable in this thesis, and this step of INTERAX should be adjusted from dividing time horizon to remaining on only one time horizon: for example, what will happen in 5 years.

Both INTERAX and IFS need to perform ***cross-impact analysis (CIA)*** in the process. The goal of the cross-impact analysis technique is to identify the possible chain occurrences of events and the probability of the happening of one event occurring another one (Alcamo & Henrichs, 2008; Amer et al., 2013). IFS starts to use its own software programme whose last version was updated in 1998 (Millett & Mahadevan, 2005), the algorithm is not understandable as limited information is given in the literature (Amer et al., 2013; Bradfield et al., 2005; Huss & Honton, 1987). This approach is then discarded for this thesis. INTERAX suggests using cross-impact analysis and trend-impact analysis in this step (step 7). Trend-impact analysis refers to the analysis of impacts of ***possible future events*** on ***key indicators***. While the cross-impact analysis examines the impact of ***possible future events*** on ***possible future events*** (Amer et al., 2013; Huss & Honton, 1987).

An example of CIA is illustrated by Pillkahn (2008). The first steps include a cross-impact analysis and evaluation from which the decisive events can be identified (Figure 3.3.1). This is an analysis of the impact relationship between one element and others, essential events that have especially strong impacts on others are selected (Pillkahn, 2008).



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Active Score
T1		3	3	3	2	3	3	2	1	2	22
T2	0		3	0	3	0	2	0	1	2	11
T3	1	1		0	0	0	2	1	0	0	4
T4	2	2	3		3	2	3	1	1	2	16
T5	0	2	3	0		0	2	1	1	3	13
T6	2	1	3	1	1		1	0	1	2	13
T7	1	2	2	2	2	1		3	2	3	18
T8	2	3	3	1	1	0	3		1	2	16
T9	2	1	0	2	1	2	2	2		1	13
T10	3	3	3	3	3	0	2	2	1		20
Score	15	18	23	12	16	8	20	12	9	17	

Active: T1 T7 T10
Passive: T2 T3 T7

0 Independent 2 Dependent
1 Slight impact 3 Strong driver

Figure 3.3.1 Cross-impact analysis and evaluation (Pillkahn, 2008, p204)

The next step of CIA is to put these events into a morphological-like analysis where the chains of causality can be found through these events. This is also one of the strengths that the cross-impact method provides, that the chains of causality are forced to be found through analysis

(Glenn & Gordon, 2009). Figure 3.3.2 shows the final step of CIA: the consistency analysis. It indicates the occurrence of a certain development of an event may positively, neutrally, or negatively change the probabilities of the occurrence of the development possibilities of other events.

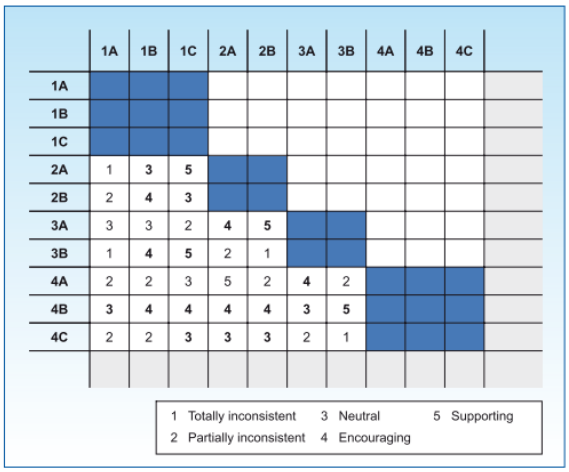


Figure 3.3.2 Consistency analysis of cross-impact analysis (Pillkahn, 2008, p205)

After the cross-impact analysis, the final step of INTERAX is to *run the model* through *Monte Carlo simulation* (Amer et al., 2013; Bradfield et al., 2005; Huss & Honton, 1987). The *Monte Carlo simulation*, in this case, is developed with *conditional probabilities* between events, key indicators and each other. *Monte Carlo simulation* is a technique that is used to model the probability of different sets of outcomes when the results cannot be easily predicted due to the difficulty or impossibility of modelling the problems in closed form (Glenn & Gordon, 2009; Kenton, 2020). After enough simulations, the range of demand estimate will be identified, the range can be divided into sub-ranges with probabilities of the demand estimate occurring in each sub-range. Different scenarios, together with different demand estimates and their probabilities of occurring are then identified.

However, it should be noted here that it is not realistic to conduct a fully comprehensive CIA and run the simulation model in this thesis, as identifying conditional probabilities requires a large amount of investigation that is not feasible due to the time and data limitation. The whole CIA process requires extensive research as every combination needs to be investigated separately. Pillkahn (2008) stated in his book that the imprecise evaluation of imprecise input variables will result in a less convincing analysis - a quantification of guts. Another important reason why a comprehensive CIA and simulation model should not be conducted is that: conducting these steps develops the probabilities of scenarios' occurrences, this is not the purpose of the to-be-proposed methodology in this thesis.

Therefore, alternatives to the CIA model analysis should be identified. The approach of CIA model analysis that is used in INTERAX is described as the 'maximum approach' by Pillkahn (2008). Pilkahn (2008) also proposed two other approaches which can be used as alternatives to the 'maximum approach'. The first one is called the '***minimum approach***', it is suitable when the analysis of all *possible future events* (thereafter called 'trends') reveals that two major criteria will be sufficient and allow the scenarios to be developed (Pillkahn, 2008). This approach is also called '***the double uncertainty'***, or a ***2x2 matrix approach*** (Amer et al., 2013).

Scenarios are developed in each of the four quadrants, which are divided by two axes that represent the most important and uncertain factors as presented in Figure 3.3.3 (Amer et al., 2013; Pillkahn, 2008). This approach was also adopted to develop scenarios for real estate within public organisations (Dewulf et al., 1999).

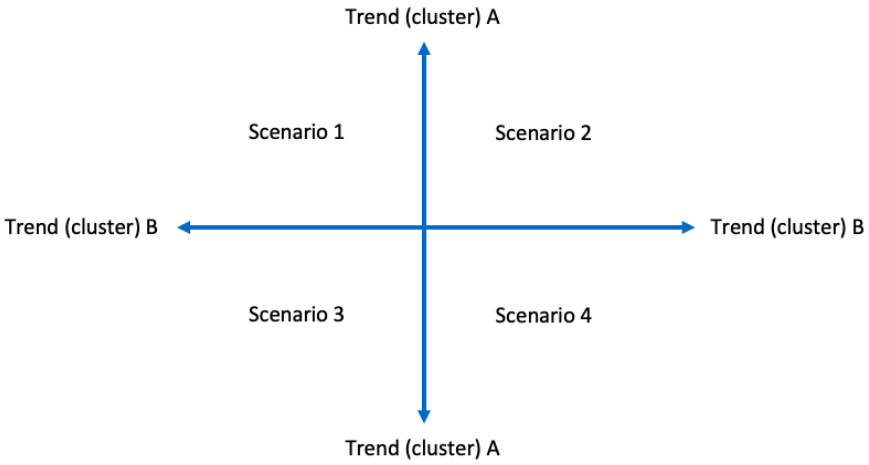


Figure 3.3.3 2x2 matrix approach (own illustration, based on Pillkahn (2008))

This approach will be adopted when the analysis of possible future trends shows that the trends can be clustered into two major trends clusters with low predictability and high impact on real estate (Amer et al., 2013; Dewulf et al., 1999; Pillkahn, 2008).

Another approach proposed by Pilkhan (2008) is called the '***standard approach***', also known as 'morphological analysis'. After identifying all the possible future trends, critical trends with high occurrence and projection uncertainty and high impact on future development. The number trends are usually more than two, each trend is drafted with at least two possible development variations. The combination of variations of trends (called as 'elements' in figure 2.1.8) which are not contradictory and fit together is regarded as a plausible future scenario (Amer et al., 2013; Pillkahn, 2008). In the example presented in figure 3.3.4, four scenarios are identified.

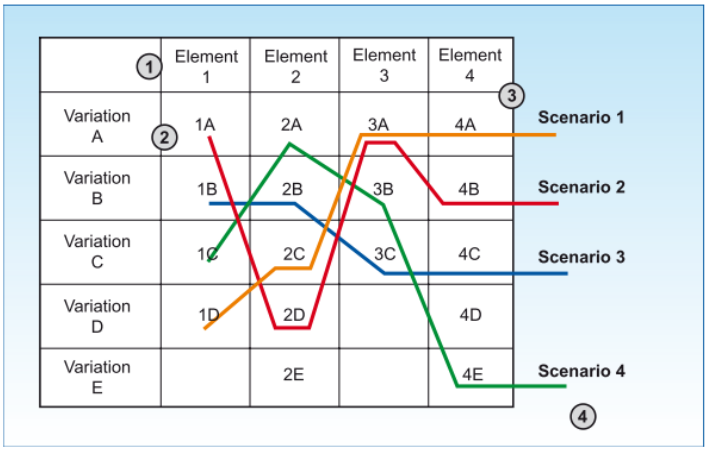


Figure 3.3.4 Morphological analysis: the scenarios are dependent on the variation of the individual elements (trends) of the future. (Pillkahn, 2008, p203)

As for this thesis, this approach will be adopted when the overview of identified trends (clusters) reveals that more than 2 uncertain criteria (clustered trends) are needed to determine and develop scenarios, while if the uncertain criteria can be clustered/reduced to 2, a 2x2 matrix approach will be adopted (Pillkahn, 2008).

The ***2x2 matrix approach*** and ***morphological analysis*** are not as in-depth as a comprehensive cross-impact analysis, neither of these two can provide scenarios with corresponding occurrence probabilities, as it is the Monte-Carlo analysis in cross-impact analysis that gives this output (Amer et al., 2013). Yet this does not mean that scenarios developed by the ***2x2 matrix approach*** and ***morphological analysis*** are not valuable. As a matter of fact, the quantitative approach to developing scenarios with probabilities has been criticised by many researchers (Amer et al., 2013). Despite that various techniques have been developed to quantitatively develop scenarios, they are still highly subjective and developing scenarios per se is supposed to be qualitative by nature (Martino, 2003). Because strict qualitative scenario planning methods only rely on historical data and assume that future trends are currently prevailing ones, they are often criticised (Amer et al., 2013; Gordon, 1994).

Yet this does not necessarily make the scenarios 'not quantitative': the scenario developing process may lack quantitative techniques in terms of probabilistic simulation modelling, but the detailed descriptions of the scenarios can still be quantitative (Amer et al., 2013). For this thesis, the outcome of scenarios has to be partly quantitative, because the key indicators and office space demand estimates are part of the scenario descriptions – and they are quantitative. Through proper research of application of the methodology, bandwidths of key indicators can be identified, and certain values from these bandwidths can be assigned to each scenario, thus making the outcome of scenarios quantitative.

Therefore, the methodology of scenario planning to be adopted in this research is presented in table 3.3.2. The scope of the scenario will be defined first, this includes defining the issue and time period. Key indicators and possible future trends are identified, and the impacts of trends on trends and trends on key indicators are also identified. A cross-impact analysis model is then established. Based on the previous argument, scenarios will be developed based on a *2x2 impact matrix approach* or *morphological analysis*. The trends presented in CIA model will be evaluated, and one of the two approaches will be adopted based on research development. After initial scenarios are developed, bandwidths of key indicators will be developed – this is part of the quantitative description of scenarios. Values from the bandwidths will be assigned to scenarios, and office space demand can then be identified, thus detailed scenarios are developed.

Scenario generation steps	
The topic	1. Defining the issue and time period of analysis
Key decision	2. Identifying key indicators
Influencing factors	3. Identifying the possible future trends

Cross-impact analysis	4. Identifying impacts of trends on trends and key indicators 5. Establishing cross-impact analysis model
Initial scenarios	6. Developing initial scenarios by 2x2 impact matrix approach or morphological analysis.
Detailed scenarios	7. Projecting bandwidths of key indicators 8. Preparing office space demand forecasts
Implications	9. Studying implications

Table 3.3.2 Proposed scenario generation steps (Own illustration)

A conceptual example of the cross-impact analysis model in step 5 is presented in Figure 3.3.5, the flows of possible future trends in this figure only indicate the concept and do not indicate the actual situation when it is applied to a certain case.

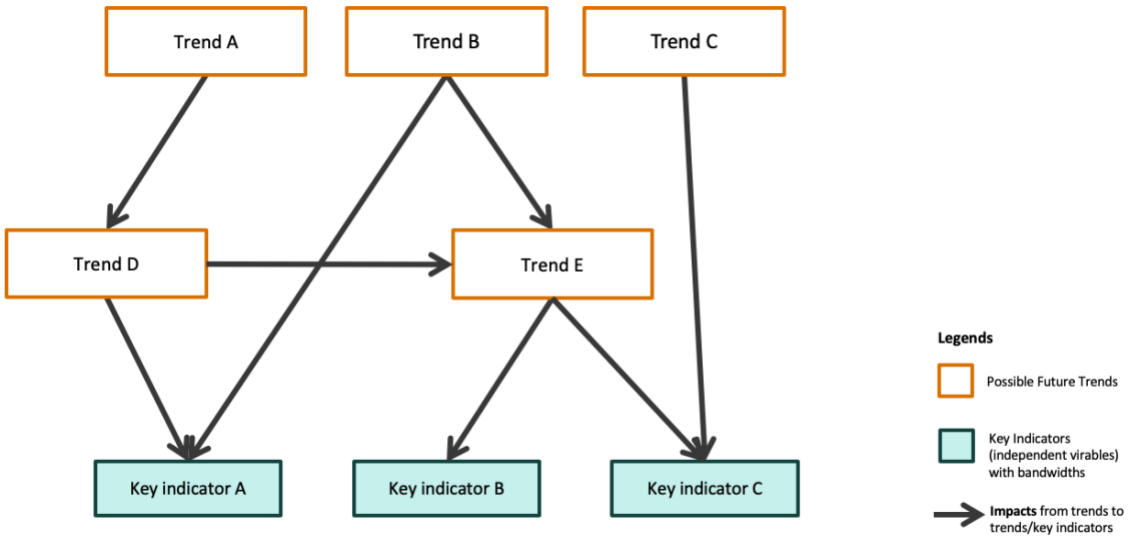


Figure 3.3.5 Conceptual CIA model (Own figure)

4 Office space demand forecast

This chapter answers sub-question 2: What is a suitable mathematical formula of office space demand forecasting for corporate real estate in the post-pandemic context? In the design process cycle, answering sub-question 2 is to calibrate the design.

To answer this question, office space demand forecast methodologies are examined in section 4.1. A preliminary formula is proposed. Sub-question 2 asks the formula at a corporate level and in the post-pandemic context, and the impacts of post-pandemic future trends such as hybrid working can be reflected on the office space demand forecast formula. Therefore, the formula is modified based on possible future trends of CRE office workplace in section 4.2. At the end of section 4.2, a suitable formula is proposed, sub-question 2 is answered.

It is notable that by specifying the proposed formula, certain steps of the proposed scenario planning methodology are already conducted. The output of these steps, including the proposed formula and the CIA model, is used in the pilot study. The argumentation of such motive is illustrated at the beginning of section 4.2.

4.1 Office space demand forecast methodologies

Two main approaches of real estate forecasting are categorised by Brooks & Tsolacos (2010) in Figure 4.1.1, representing the quantitative approach and qualitative approach. Brooks & Tsolacos (2010) attempted to apply these two approaches together to the real estate field, as they can complement each other in most cases.

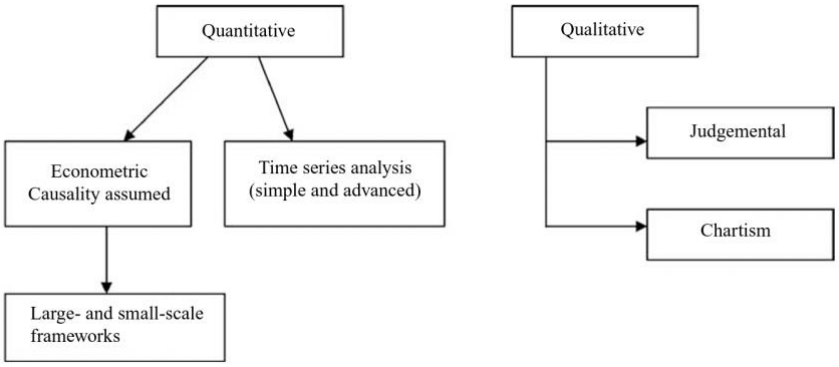


Figure 4.1.1 Summary of forecast approaches, (Brooks & Tsolacos, 2010, p9)

'Scenario analysis' is considered as one of the objectives of forecasting work in the book of Brooks & Tsolacos (2010). As regression analysis remains the foundation of quantitative modelling work, scenario analysis can be conducted straightforward from the regression model by inputting different values of contingencies to allow different values for the dependent variables. Brooks & Tsolacos (2010) stated that the value of forecasts would be maximised if the contingencies are applied in the model, which means scenario analysis is

welcomed to be included in the forecasts. It is also concluded that the optimal approach of forecasting is the combination of 'judgemental' (qualitative) and quantitative forecasting.

Hence, using the output from scenario planning as dependent variables in the formula of demand forecast will result in different forecasts per scenario. This would be beneficial for decision-makers in the real estate development process, particularly the CRE decision-makers for this thesis.

Rabianski & Gibler (2007) wrote a literature review of office market demand analysis and estimation techniques. It is identified that empirical models of real estate markets can be classified into two basic types: econometric and judgmental. The judgmental here is different from the 'judgemental' mentioned above, the judgmental type here refers to the two threads of demand forecasting introduced in the next paragraph. A conclusion of econometric techniques is that office space demand can be calculated by a function of rent and employment. However, while econometric techniques resulted in more sophisticated modelling techniques, they did not lead to a more comprehensive understanding of market dynamics. As office users are not homogeneous, different office sectors have been developing distinctive spatial and temporal variations. In order to deal with the momentous changes regarding technology, environment, society, etc., market research in terms of office market demand is called for.

Two main threads of office space demand forecasting are identified by Rabianski & Gibler (2007). One is called the ***Ratio Method*** which uses certain types of ratios to connect population and employment to office space demand. This method was first stated in the following manner:

$$D_{t+1} = \left(\frac{S}{P}\right) P_{t+1}.$$

Where:

D_{t+1} = Demand for total office space in the time period t+1
S = Stock of office space in a certain period
P = Population in a certain period
S/P = Average of the ratio in several recent years
P_{t+1} = Forecasted population in the time period t+1

This method has its obvious drawbacks, which were mentioned by several researchers (Rabianski & Gibler, 2007). As the office markets are heterogeneous, applying such ratio S/P in a different regional and economic context is unrealistic. The modifications in work practices could impact the ratio. However, this method is still appealing due to the limited data needed for the calculations. Using this method, wherein the ratio can be office space to population or office space to employment, can be a check on the office space demand forecast under the form of Forecasting Equation Method.

The other method is called the ***Forecasting Equation Method*** which uses an estimating equation that contains a set of variables that directly create demand for office space (Rabianski & Gibler, 2007). It also addresses the heterogeneity in the modern office market

by stratifying employment by industry in order to achieve the variance in industry differences and their office demand. It is also stated that any estimation of net demand should include a normal vacancy rate.

The estimating equation for net office demand is finalised in the following (Rabianski & Gibler, 2007):

$$D^* - S = \left(\frac{1}{1 - V_n}\right)(\beta G + G + O_r) - (O_a + O_v).$$

Where:

D^* = Total demand of office space, including normal vacant space
S = Supply of office space
V_n = A "normal, desirable" vacancy rate
βG = U = d_4 = Existing tenants upgrading their space requirements
β = a rate derived from historic data or informed judgment to relate U and G
G = Net additional office space demand from employment
= $\alpha[(d_1 + d_2 + d_3) - (s_1 + s_2 + s_3)]$
α = Average space used per office employee
d_1 = Existing tenants expanding their space requirements
d_2 = New tenants moving into the community, relocating firms
d_3 = New tenants emerging from start-up business venture in the area
s_1 = Existing tenants going out of business reducing their space requirements
s_2 = Existing tenants reducing space requirements
s_3 = Existing tenants moving out of the community, relocating firms
O_r = d_5 = Existing tenants in buildings forced to relocate because their present office space is being removed from the inventory
O_α = s_4 = New office space being added (including conversion from one class to another as well as conversion to/from non-office space from/ to office space)
O_v = s_5 = Vacant space from the previous period (office overhang)

It is notable that ***(D* - S)*** stands for the net demand, which is simply total demand subtracting the current supply. ***D**** stands for the total demand of office space. What else can be clarified in this model is that: d_1 to d_5 are the five factors of the demand for additional office space, and s_1 to s_5 are the corollary five factors of the supply of available space in the office market (Rabianski & Gibler, 2007). While the model looks cumbersome, it is simply an elaborate version of:

Total space of demand (of a time period) = Existing space of supply + Net additional space of demand from employment + demand from upgrading + demand from relocation – new supply – existing vacant space.

Rabianski & Gibler (2007) further discussed the problems of disaggregation, segmentation, target marketing, and market demand variables and modelling. The need to allocate demand and employment to different geographic submarkets in a certain region and the class of space demanded is identified. It is also stated that there is a need to estimate the proportion of employees in different industries who will occupy physical office space and the space needed

per employee in different industries. Based on these segmentations, a stock and a flow ***disaggregated demand model*** are provided.

$$D = \alpha\beta\Phi\theta\pi\tau\gamma E_T.$$

$$\Delta D = \alpha\beta\Phi\theta\pi\tau\gamma(\Delta E_T).$$

Where:

D = Demand for disaggregated and segmented existing office space;
ΔD = Demand for additional disaggregated and segmented office space;
α = Percentage of private sector employment by SIC code allocated to the office node;
β = Percentage of private sector employees allocated to the Class space;
Φ = Office space per private sector employee;
θ = Percentage of private sector employees who occupy office space;
π = Percentage of total employment in the private sector;
τ = Percentage of private sector employment in tenant-occupied space;
γ = Percentage of private sector employment in general office space; and
E_T = Total employment.

While lots of data is specifically required, the basic logic behind this model can be interpreted as:

*Demand for a certain segmented office space = Office space per employee * Percentage of the employment who will occupy tenant-occupied office space * Percentage of the segmented employment in total employment * Total employment*

EIB (2011) performed office space demand forecasts in Utrecht, a similar approach to the previously-mentioned model is used in this research with the time scope of 2020-2040. The steps that were taken include: 1. Drawing up employment forecasts per sector; 2. Translating employment forecasts to office-based employment per sector; and 3. Translating office-based employment per sector to office space forecasts based on the average use of space by employees per sector. The basic logic of this formula complies with the ***disaggregated demand model***, however, it is only feasible for space demand forecast at a (Dutch) regional level. Although the formula used by EIB (2011) cannot be adopted for this thesis, the same logic can be applied to the formula in this thesis. Therefore, a (preliminary) formula can be proposed:

$$D = \sum \Delta D = \sum \Delta\gamma \times \Delta\beta \times \Delta\theta$$

Where:

D = Total demand of office space
γ = **Average use of space** needed per employee who occupies office space
β = **Percentage of employees** who occupy office space
θ = The **employment headcount** classified by different employee groups

It is notable that the office space demand forecast models that are explained in this sub-section are originally served for forecast on the stock level. However, the preliminary formula that is proposed above uses merely the basic logic behind the ***disaggregated demand model***, it can be used to further develop a formula that is suitable for forecasting on a CRE level.

4.2 Possible future trends of CRE office workplace

This section is to improve the preliminary office space demand formula that is proposed in section 4.1. The improved formula focuses on office space demand forecasting at a corporate level and the context of post-pandemic.

The literature study on possible future trends of CRE office workplace is conducted. This is because possible future trends have impacts on the office space demand. By modifying and specifying the independent variables in the formula, such impacts are reflected. Sub-question 2 is then answered.

The formula being improved means that the independent variables (key indicators) are identified. At the same time, possible future trends and the impacts of trends on trends, trends on key indicators are also identified. The CIA (cross-impact analysis) model can then be established. This means that steps 2-5 of the proposed scenario planning methodology would have been finished in this section.

It should be clarified that steps 2-5 are finished at a relatively generic level – before applying the proposed methodology to a case. Not yet applying to a case means that step 1 'defining the issue and time period of analysis' also remains at a generic level: the scope is 'post-(COVID-19)pandemic office space demand scenarios at a corporation level in the Netherlands', no more specific information is determined. The outputs from completing steps 2-5 are further used in the pilot study. The argumentation of such feasibility is given in chapter 5.

The search query that was used for this literature study is:

TITLE-ABS-KEY (organi?ation AND workspace OR workplace AND "real estate") OR TITLE-ABS-KEY ("corporate real estate" AND workspace OR workplace OR "office space") OR TITLE-ABS-KEY (organi?ation OR corporation OR "corporate real estate" AND workspace OR workplace AND layout OR "office space")

366 documents were found on Scopus via this query. Besides the scientific papers, commercial research documents regarding the future of workplace made by consultancy companies such as CBRE, JLL were also adopted. This is because relevant commercial research helps reveal the current market landscape, including lastest industry trends, and as a relatively new topic, academic research may not cover all market updates.

After examining the scientific and commercial research, 32 documents were adopted in the desk research and they were categorised into 3 topics: Activity-based working (ABW), Hybrid working, and Smart building solutions. The literature research summary is attached in

Appendix C, while a more concise summary is included in this chapter. These three topics form the first three sub-sections of section 4.2.

After these sub-sections, the proposed office space demand forecasting formula is indicated in section 2.2.4. Sub-question 2 is answered.

4.2.1 Activity-based working (ABW)

In this sub-section, the topic of ABW is examined. Table 4.2.1 provides a summary of findings from the literature. Through discussing ABW, alternative independent variables of the formula are identified and defined, the formula proposed in the last section is improved. Possible future trends (ABW and its relevant trends) are also identified in the text to build up the CIA model.

Source	Major findings
Understanding the Mechanisms of Activity-based Workspaces: A Case Study (Eismann et al., 2021)	ABW consists of three components: **(1) desk sharing, (2) core functional spaces, and (3) supportive functional spaces.** Core functional spaces are classified by two dimensions: closed-open workspace and individual-team workspace.
Activity-based flexible office: Exploring the fit between physical environment qualities and user needs impacting satisfaction, communication, collaboration and productivity (Zamani & Gum, 2019)	Collaboration appears more in ABW compared to the normal workplace, especially in more visible and accessible open areas. Providing single-occupant enclosed rooms would increase concentrated individual work and privacy. Defining certain areas for teams that require high intra-team collaboration would be better than merely establishing unassigned workstation.
The mindset of activity-based working (Skogland, 2017)	Although spatial changes may well facilitate the intentions, yet such effects are not easy to predict before implementing. Managerial issues and concerns need to be addressed continuously during the whole implementing process of ABW.
Desk ownership in the workplace: The effect of non-territorial working on employee workplace satisfaction, perceived productivity and health (Kim et al., 2016)	Reducing space per person under the purpose of implementing non-territorial work policy ***does not necessarily*** decrease occupant workplace satisfaction, perceived productivity, and health. Spatial layout design needs to be carefully treated to reflect the actual requirements of all kinds of organisational work processes.
Accommodating new ways of working: lessons from best practices and worst cases (Brunia et al., 2016)	Large open workspaces that accommodate more than 15 people should be avoided or sufficient acoustic measures are needed to solve privacy or concentration issues. Open spaces should not be too large, better divided.
An end-user's perspective on activity-based office concepts(Appel-Meulenbroek et al., 2011)	Workplace implementation should be decided by the nature of work-related activities and the personal aspects of users. Employees' personal preferences might have a bigger impact on the final satisfaction than the certain types of workplaces that are expected to be effective and satisfactory. Corporate real estate managers should seek a method that could identify the way of ABW will be actually adapted by the employees.
Comparative study of the factors affecting the generativity of office spaces (Asefi et al., 2019)	Basic individual needs should not be sacrificed due to the need of promoting interaction, teamwork and collaboration.
Are the myths of space utilization costing you more than you know? (Knapp et al., 2009)	European is shifting its metric focus from sqm per seat to occupancy rate. This states the necessity of considering both of them which are reflected accordingly by ABS and hybrid working.
Future office layouts for large organisations: workplace specialist and design firms' perspective(Nanayakkara et al., 2021)	Main considerations when organisations design new office layouts are flexibility, functionality, leading technology, acoustic settings, sense of community and generation gap between employees.
Productivity drivers of knowledge workers in the central London office environment (Chadburn et al., 2017)	There is usually more acceptance of open workspace after knowledge workers experience it. The acceptance is reflected by improved teamwork and communication in an open workspace.

Source	Major findings
The changing nature of the workplace and the future of office space (Harris, 2015)	Many organisations plan their space at around eight desks per ten workers, that is, as the share-ratio of 1,25. In the future, the collaborative, meeting and social space will increase in order to enable the increasing needs of knowledge sharing and interaction. At the same time, conventional desk space will decrease with the promotion of WFH and hot-desk settings.
Workplace trends in office space: Implications for future office demand (Miller, 2014)	Office space per worker will decline over time, especially in the larger tenants that actually analyse how to use space more efficiently. Such decreases are mostly based on increasing utilisation rates.
Working in the world of the pandemic. (Tredinnick & Laybats, 2020)	More flexible working arrangements will become the norm, rather than the exception. More materials will be digitised. We'll have less physical space.
The Tetris office: Flex work, real estate and city planning in Silicon Valley North, Canada (Pajević, 2021)	**Activity-based planning** allows for more flexible uses of space, so the office is not just shrinking, but is also expanding on a need-to basis — in other words, the office increasingly resembles a Tetris game, whereby pieces are assembled and disassembled continuously.
Van hybride werken naar activity based werken (Verwimp et al., 2021)	Activity-based working might cause employees WFH more time, as they would realise that some tasks can be finished at home

Table 4.2.1 Summary of literature study of ABW (Own table)

The core of the term activity-based working (ABW) is that employees have no personal work-settings[3], they choose freely between several work-settings based on their specific tasks, and these work-settings are shared by employees – employees do not have their own desks (Appel-Meulenbroek et al., 2011; Bäcklander et al., 2021; Eismann et al., 2021; Verwimp et al., 2021).

However, the definitions of ABW are slightly different in different papers. Although all papers agree that ABW is about desk-sharing so employees can work 'anywhere' (Zamani & Gum, 2019), the scope of 'anywhere' differs in various papers. Some specifically indicated that 'home workplace' is an option for 'individual concentration task' and 'short briefing tasks' in ABW (Verwimp et al., 2021, p. 11), some mentioned that work may not be 'office-based' yet still defined activity-based workplace as a workplace exclusively in the office (Appel-Meulenbroek et al., 2011; Zamani & Gum, 2019). Through examining definitions of ABW, it can be concluded that a general ABW includes home workplace as a work-setting option (Verwimp et al., 2021), and a narrow ABW exclusively refers to an ABW environment that is physically in the office (Appel-Meulenbroek et al., 2011; Skogland, 2017; Zamani & Gum, 2019). Notably, while adding home workplace into work-setting options is undoubtfully reasonable, a 'home workplace' is not a 'task' – the work-related tasks in an organisation will not change no matter ABW considers home workplace as an option or not.

In this thesis, the term ABW is defined narrowly as 'an activity-based working ***office*** environment where office users share work-settings and choose to work in different work-settings based on their tasks'. The 'home workplace' and other hybrid working options is outside of the scope of ABW, and they are related to 'hybrid working' that is discussed in the next sub-section.

[3] In this research, work-setting is defined as a workspace where an employee conducts her/his/their work. For example, a work-setting can be an individual workstation, a touch-down desk, a focus room, a phone booth, etc.

In an ABW environment, employees sharing the workspace means that it is allowed for more flexible uses of space, so the office is not just shrinking but also expanding on a need-to basis (Pajević, 2021). ABW does not necessarily mean the reduction of office space or the deduction of cost, although the implementation of ABW may lead to either of these (Hunt et al., 1998; Pajević, 2021). Corporations might not meet their expectations if they set the goal of ABW as reducing office space or cost, whereas employees' productivity, health, and creativity, etc., can all be positively or negatively affected by the implementation of ABW (Eismann et al., 2021; Kim et al., 2016).

The space types of ABW can be categorised as ***Core Functional Spaces*** which includes open/enclosed and collaborative/individual area, and ***Supportive Functional Spaces*** (Eismann et al., 2021). The actual needed functional spaces are decided by the ***nature of work-related activities*** and ***personal aspects*** (Appel-Meulenbroek et al., 2011). Research has indicated that individual needs should not be dismissed or even sacrificed (Asefi et al., 2019; Brunia et al., 2016; Eismann et al., 2021). This means that it would be more precise and beneficial to categorise the employees into different groups of ***work-related activity types*** and different groups of ***personal requirements***.

Referring to the preliminary formula, it has been identified that employees need to be categorised and an 'average use of space per employee' will be assigned to each categorisation. It is obvious that the average space per employee will change to a certain extent when new working methods and office layouts are implemented. However, it is ***not*** easy to simply modify the average space per employee, nor is this the trend of organisations predicting the space they need in Europe (Knapp et al., 2009). This way of calculating the total space area is especially inappreciable when new ways of working (e.g. ABW) is implemented, as this number is usually derived reversely when the total office space and headcount of employees are known. Therefore, it is more straightforward and trustworthy to classify employees and examine ***(1) the number of seats the office needs, (2) the kinds of seats that should be implemented, (3) the proportion of every certain kind of seat*** and ***(4) the area that every certain kind of seat needs*** per employee group, in order to improve the formula.

The number of seats the office needs is directly related to the number of employees. Yet in an ABW workplace environment, the number of employees is not equal to the number of the (individual workplace) seats. Regardless of the effects of hybrid working (the possibility of WFH), different ***personal requirements*** already lead to different requirements of seat count. Employees who spend most of the time on their own individual desks would more likely need one seat per person – assigned seat, while more adaptive employees and constant travellers would not need assigned seats for themselves as they are less dedicated to individual seats or even the office. A term of ***share-ratio*** can be defined here, that is, the ratio of the number of employees to the number of seats (share-ratio = employee headcount / seat count[4]). Employee groups with different personal requirements have different share-ratios - depending on their engagement to an individual workplace seat. It is necessary to group the employees based on their personal requirements for seats, and a certain share-ratio can be assigned to each group. For examples: an employee who spends all the time on an individual

[4] The **seat count** means individual workplace desk count. It does not include the seats in collaboration space, meeting rooms, etc.

workplace seat would have a share-ratio of 1; an employee who spends half of the working hours on an individual workplace seat and another half in a meeting room and collaboration space would have a share-ratio of 2. The ***share-ratio*** mentioned here ***only*** take ABW implementation into account, but it does ***not*** consider the effect of hybrid working yet. Therefore, classifying employees by their personal requirements can help derive ***the number of seats the office needs*** via ***share-ratio.***

Besides classifying employees based on their personal requirements, an other classification is also identified earlier: to classify employees based on their work-related activity types. **Work-related activity types** are identified through the activities, mobility and collaboration profiles of different teams, the differences of work-related activity types are reflected by different functional needs (Appel-Meulenbroek et al., 2011). Functional needs refer to ***the kinds of seats that should be implemented, the proportion of every certain kind of seat*** and ***the area that every certain kind of seat needs***. The last one: *the area of every certain kind of seat* is usually fixed in large organisations due to their own protocols, legal requirements and certain facility supplier. If considering it fixed, the first two can be reflected by an ***'ABW implementation plan'***. With given numbers of needed desks per employee group, ABW implementation plan distributes the total number as different kinds of individual seats, thus further calculating the total office space. Therefore, employee groups categorised by different work-related activity types should have different ABW implementation plans, which consists of ***the kinds of seats that should be implemented, the proportion of every certain kind of seat*** and ***the area that every certain kind of seat needs***.

Therefore, employees need to be classified twice into two sets of groups. The first one is based on ***personal requirements*** which further decides what is the seat count within each group via ***share-ratio***. The second one is based on ***work-related activity types*** which can be further assigned with ***ABW implementation plans***. Each employee belongs to one group of personal requirements and one group of work-related activity types, an ***employment structure*** is then established.

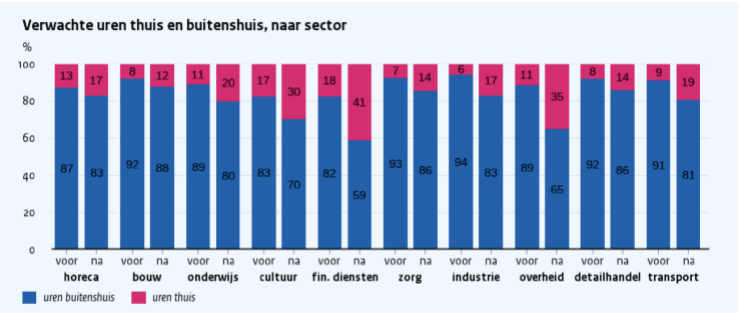
Employment structure, ABW implementation plan, and ***share-ratio*** together derive the total office space demand. Notably, ***no*** value of these three will be certain in the future. ***Employment structure*** is impacted by the total personnel which may be impacted by economic development and/or corporation decisions, and it may also be impacted by the change of employees' personal requirements and/or work-related activities. ***ABW implementation plan*** is established based on work-related activity, while work-related activity is impacted by the development of facilities (technology), and the change of work behaviour initiated by the corporation and/or employees, etc (Appel-Meulenbroek et al., 2011). ***Share-ratio*** can be impacted by the trends of hybrid working, which will be elaborated in the next sub-section. *The bandwidths of all these three components should be developed when developing scenarios.*

To improve the office space demand forecasting formula, it can be identified that ***ABW implementation plan*** can replace 'Average use of space needed per employee who occupies office space', ***share-ratio*** can replace 'Percentage of employees who occupy office space', and ***employment structure*** enhances 'The employment headcount classified by different

employee groups' by indicating the classification types'. Due to the fact that other trends have not been examined, the improved formula will be proposed at the end of this section.

4.2.2 Hybrid working

In this sub-section, the topic of hybrid working is examined. Table 4.2.2 provides a summary of findings from the scientific literature and commercial papers. Through discussing hybrid working, specific formulas are proposed in order to compute some of the alternative independent variables that are identified in the last sub-section. Possible future trends (hybrid working and its relevant trends) are also identified in the text to build up the CIA model.

Source	Major findings
CfPB Persbericht Thuiswerk productiever dan kantoorwerk (Hoekjen & Hoekstra, 2021)	**82%** of the respondents in the wewerkenthuis survey indicate that they want to work from home (WFH) more often after corona; **87% of the respondents would not mind having to WFH for one or two days.** "We also asked about the number of hours people want to work from home," says Hoekstra. "The number of 16 hours is mentioned most often (more than 20%), followed by 24 hours (approximately 17%) and then 8 and 20 hours (approximately 10%)."
Thuiswerken vóór, tijdens en ná de coronacrisis(Jongen et al., 2021)	It is expected that after the pandemic there will be **twice as much working** from home as before the corona crisis, but most of the working hours will still take place at the workplace. Before the corona outbreak, they worked at home on average for almost 4 hours a week. This is expected to be **8 hours a week after the corona crisis**.  *Figure 4.2.1 Share of hours worked away from home and at home: before the and expected after the corona crisis by sector (Jongen et al., 2021, p. 4)* **Regarding the effect of WFH/hybrid work mode on productivity:** Employers generally have few losses with an increase in home working, according to the empirical literature, working from home usually leads to higher productivity. Several causes of this higher productivity are mentioned in the literature. The factors mentioned most are a reduced travel time (Kazekami, 2020), increased well-being (Bosua et al., 2012), fewer interruptions by colleagues (Bailey and Kurland, 2002).
The impact of COVID-19 pandemic on conventional work settings (Diab-Bahman & Al-Enzi, 2020)	**More than half of the respondents supported the idea of a hybrid model**. **More than 70%** of employees currently working from home reported that they can accomplish **at least 60–70%** of the expected workload. **More than half** of the respondents indicated that they could **achieve at least 80–90%** of the currently expected workload if a hybrid model of onsite and at-

Source	Major findings
	home work is established.
JLL Perspectives for Enterprises 2021 [Webinar] (JLL, 2021a)	From employees' perspective, **50% of them want to work in hybrid mode after COVID, 26% choose exclusively outside of the office**, and the other 24% choose exclusively in the office.
Global office impact study & recovery timing (Cushman & Wakefield, 2020a)	The share of people permanently WFH in the US and Europe increases from 5-6% pre-COVID-19 to **10-11% post-COVID-19** and that the share of agile workers who work in a hybrid mode increases from 32-36% **to just under 50%**.
Workplace Ecosystems of the Future (Cushman & Wakefield, 2020c)	The workplace of the future will be an ecosystem of multiple options for workers. **In the post-pandemic world, remote working ranges from 1,5 days to 3 days per week in general.** It is very unlikely that the average levels of WFH will go beyond 3 days per week in the long term in the US. The results showed that the 'most-likely' situation of WFH is 2,25 days per week, the 'lowest' situation of WFH is 1,5 days per week, and the 'highest' is 2,9 days per week. When comparing the percentages of office workers usually (more than 2,5 days per week) WFH between the US and the Netherlands in 2019, it can be found that this percentage of US is 8,5% and it is 14,1% for the Netherlands (Cushman & Wakefield, 2020b; eurostat, 2021b, 2021a). The huge difference of the pre-COVID-19 data makes it very possible that the probable bandwidth of average WFH days post-COVID-19 in the Netherlands is different from that of the US, and the 'highest' end is more likely to be even 'higher' in the Netherlands.
The influence of the COVID-19 pandemic on the digital transformation of work (Nagel, 2020)	**People believe that digital transformation of work will spread faster, due to their experience with the COVID-19 pandemic.** The more people believe in an increased spread of digital transformation due to the COVID-19 pandemic, the more likely they are to imagine working exclusively digitally in the future.
Future of offices: in a post-pandemic world (ARUP, 2020)	With expenses in everything from energy to broadband usage to office rent reduced, many organisations will see remote working as an opportunity to cut some of their biggest financial commitments. **Thus, there is potential cost saving on promoting hybrid working.**
Workplace change within the COVID-19 context: a grounded theory approach. (de Lucas Ancillo et al., 2020)	Some reports indicated that, prior to COVID-19, only 3% of the US office market was considered flexible space, while their growth was estimated at 25% annually during the last five years. While there has been a 12% and 9% decrease in working time within headquarters and satellite offices, an increase of **20% to 27% in flexible office working** is projected.

Table 4.2.2 Summary of hybrid working (Own table)

Hybrid working in essence refers to employees partly working in the office (on-site) and partly working remotely, such as from home, a café, or any location as long as it's not in the assigned office (Diab-Bahman & Al-Enzi, 2020; Saurin, 2012). While fewer people work in the actual office due to hybrid working, it is obvious that the desks and seats needed in the office will decrease, hence office space area can be cut down.

ABW is defined in the last sub-section, and ABW in this research does not include hybrid working. Therefore, hybrid working needs to be defined too. In this research, hybrid working refers to partly working in the office and partly working remotely. While work-related activities that must be done outside office, such as business travelling, meeting up clients are considered as 'working in the office', and 'working remotely' only refers to working from home or other locations where business activities do not have to happen there, such as a café, a library. In other words, conducting ABW without hybrid working means that employees work full-time in the office and do not WFH.

The number of days which employees work in the office is an important factor that determines what percentages of employees will work in the office on a day. Together with the implementation of ABW which leads to shared-desk policy, this percentage will adjust the ***share-ratio*** (Table 4.2.3), that is, ***employee headcount / seat count***. The seat count here stands for individual workplace desk count, and it excludes the seats in meeting room, collaboration space, etc. ***Share-ratio*** indicates how many employees will share one seat in the office. With the input of headcount of employees, ***share-ratio*** determines the number of desks (seats) and other facilitates that are needed in the office.

Share-ratio (=employee /seat count [5])	**Share-ratio After ABW implementation**	**ABW-implemented share-ratio After conducting hybrid-working**
1	**δ** ($\delta > 1$)	**$> \delta$**[6].
Description: Fixed-desk All users have their own desks. Employees do not share their desks with others.	Description: Shared-desk Employees do not just spend time in their individual seats, they may be in meeting rooms, collaboration space, phone-booth, or outside office for business, etc[7]. Hence, sharing individual desks among employees is doable since the desks are not full-time occupied.	Description: Shared-desk Employees can work either in the office or from home or in other locations. Thus the individual desks can be shared at a higher ratio as they eventually spend less time in the office.

Table 4.2.3 Share-ratio evolution (own illustration)

It is notable that the average number of days which employees work in the office is not the sole factor that determines the share-ratio δ. Hypothetically, if there is one specific day in a week/month when all employees must work in the office, reducing desks is not possible because there is one day when all employees will be present in the office and take up space. The share ratio in this extreme case is 1, and the average number of days employees work in the office does not make difference in the share ratio. On the other hand, if all employees' hybrid working mode is planned seamlessly every week, and there is no above-average amount of employees working in the office in any day, the average number of days which

[5] The **seat count** means individual workplace desk count. It does not include the seats in collaboration space, meeting rooms, etc.

[6] Because conducting hybrid-working while implementing ABW means that employee will spend less time in the office than when employees work full-time in the office while conducting ABW, the share-ratio is higer than it in the middle column.

[7] As defined in sub-section 4.2.1, the situations here do not include hybrid working (e.g. WFH). 'Outside office for business' only refers to business activities that must be done outside the office (e.g. business travelling, meeting up clients)

employees work in the office can maximise its value. For example, if all employees work 3 days in the office per week, every employee needs one seat in the office (share-ratio = 1, regardless of ABW), and employees' schedule of working in the office can be well planned, there will only be 60% of employees in the office every single day, and the share-ratio will become 1,67 instead of the previous number 1.

Two extreme hypotheses are provided above, yet the possibility of occurrence of either is extremely low – the former may mean that organisations do not want hybrid working to help increase share-ratio and decrease seat count, the latter will need a seamless collaboration of HR, ICT, CRE and many other departments in the office. In short, both are unrealistic. However, a probable bandwidth of share-ratio can be suggested by calculation using the number of days people will work from home while taking these two extreme hypotheses into consideration.

Therefore, if

α = the number of days employees working in the office in a week,
δ = current share-ratio = employees/seats
ε = the employee headcount

Then,

Weekly visit times to the office of employees $= \alpha \cdot \varepsilon$

Average daily visit times to the office of employees $= \frac{\alpha \cdot \varepsilon}{5}$

The (highest possible) updated share-ratio

$$= \frac{\varepsilon}{\text{(The lowest possible) amount of seats required}}$$

$$= \frac{\varepsilon}{\frac{\text{(The lowest possible) headcount of employees who visit the office}}{\delta}}$$

$$= \frac{\delta \cdot \varepsilon}{\textbf{\textit{Average daily visit times}} \text{ to the office of employees}}$$

$$= \frac{\delta \cdot \varepsilon}{\frac{\alpha \cdot \varepsilon}{5}}$$

$$= \frac{5\delta}{\alpha}$$

The bandwidth of the ***possible updated share-ratio***, without any other factors taken into consideration, is $\delta \sim \frac{5\delta}{\alpha}$.

Therefore, with an existing share-ratio that is determined ABW, two bandwidths that will result in the modification of the share-ratio can be identified.

The first bandwidth is the bandwidth of the variable: ***the number of days employees working in the office in a week. The second bandwidth*** is ***the actual change of share-ratio that is dependent on the development and cooperation of ICT and HR departments and employees' behaviours***, in other words, a bandwidth can be developed while taking the extent of participation of the corporation and employees into consideration.

Regarding the ***first bandwidth***, although an average number of days employees working in the office per week can be analysed through a certain survey that examines employees' behaviours, it is still important to create a bandwidth that is derived from the survey and additional data. The most important reason why this should be done is that the current survey does not necessarily represent the post-COVID situation.

Literature research shows that employees do like to work in a hybrid work mode, especially after their experience of WFH during COVID-19 lockdowns. The percentage of employees who would like to partly work from home and partly in the office ranges from 64% to 87% (Diab-Bahman & Al-Enzi, 2020; Hoekjen & Hoekstra, 2021; JLL, 2021a; Nagel, 2020), and such percentage is extremely high in the Netherlands as the data of 87% is analysed through the survey conducted in the Netherlands. Every paper that has been examined indicates that the productivity of WFH is higher than completely working in the office, and the productivity has remained strong in general (Cushman & Wakefield, 2020b; Diab-Bahman & Al-Enzi, 2020; Jongen et al., 2021). Research shows that the majority of people, ranging from 51% to 56%, indicated higher perceived productivity when working from home than working in the office (Cushman & Wakefield, 2020b; de Lucas Ancillo et al., 2020; Diab-Bahman & Al-Enzi, 2020; Hoekjen & Hoekstra, 2021).

Research conducted in the United States indicated that the bandwidth of the days people working in the ***office*** is 2,1 – 3,5 days with the most probable days of 2,75 (Cushman & Wakefield, 2020b); the bandwidth may even be shifted down a bit in the Netherlands due to higher acceptance, and earlier and wider adoption of hybrid working in the Netherlands (Cushman & Wakefield, 2020b; Hoekjen & Hoekstra, 2021). It is also indicated in the research that more than 40% of government employees in the Netherlands prefer to work in the ***office*** only for 2-3 days per week, and less than 10% prefer to work in the office 4 days per week (Hoekjen & Hoekstra, 2021). Regarding Dutch knowledge workers in financial, cultural and research industries, the average days of employees who want to work in the office per week range from 3 to 4 (Jongen et al., 2021).

Based on the literature research, it is suggested that the ***bandwidth of days people work in the office per week*** in Dutch organisations to be 2 - 3,5, with the most probable days around 3. This must be further justified and adjusted by the research of specific cases.

Regarding the ***second bandwidth***, ***the actual change of share-ratio***, it is found that it can be represented by the bandwidth of desk occupancy rate. For examples: if the technology is implemented well due to the high cooperation of CRE, ICT and HR departments, the occupancy rate will obviously be high while employees conducting hybrid working and ABW;

the occupancy rate will be low if the technology is not implemented well and does not allow employees to gain a real-time view of desk occupancy situation.

As the share-ratio of $\frac{5\delta}{\alpha}$ regards the desk occupancy rate as 100%, if another variable of desk occupancy η (0<γ≤100%) is added, the modified share-ratio will be:

Modified share-ratio

$$= \frac{\text{Employee}}{\text{Desk}} = \frac{\text{Employee}}{\frac{\frac{Employee}{current\ share-ratio}}{\eta}}$$

$$= \frac{\eta * \text{Employee}}{\frac{Employee}{current\ share-ratio}} = \eta * \textbf{current share} - \textbf{ratio}$$

$$= \frac{5\delta * \eta}{\alpha}$$

Therefore, the final bandwidth of **share-ratio** is

$$\frac{5 * \delta * \eta_1}{\alpha_1} \sim \frac{5 * \delta * \eta_2}{\alpha_2}$$

Where:

δ = current share-ratio sheerly based on ABW implementation
= employees/seats,
α_1 = highest average number of days employees working in the office in a week,
α_2 = lowest average number of days employees working in the office in a week,
η_1 = lowest desk occupancy rate
η_2 = highest desk occupancy rate

($0< \alpha \leq 5$, $0< \eta \leq 100\%$)

As for α_2 to α_1, the bandwidth as identified from literature research is 2 – 3,5. Yet this must be further justified and modified by data analysis and interviews to apply to a certain case. As for the value of the bandwidth of desk occupancy rate, it is more convincing if it is developed through additional information, which should be collected in the interviews in certain cases. It is notable that the highest and lowest here do ***not*** refer to the highest and lowest mathematical results mentioned before (e.g. η is unlikely to be 100%), research approaches such as interviews are needed for more plausible bandwidths.

For the purpose of improving the office space demand forecasting formula, this section identifies what the independent variables of the ***share-ratio*** are: ***average number of days***

employees work in the office in a week, and ***desk occupancy rate***. The formula is then further specified.

4.2.3 Smart building solutions

In this sub-section, the topic of smart building solutions is examined. Table 4.2.4 provides a summary of findings from the scientific literature and commercial papers. Through discussing smart building solutions, it is identified that this topic is an important possible future trend that impacts certain independent variables such as occupancy rate, hence the CIA model can be elaborated.

Source	**Major findings**
JLL Perspectives for Enterprises 2021 [Webinar] (JLL, 2021a)	Health & wellness of employees is a #1 priority for EMEA CRE directors in the medium to long term, while technology is #2. Top investment areas are well-being service, WFH solutions, collaboration tools in the office.
Focus 15: Analytics and Pandemics: What's Changed? [CoreNet Webinar] (Targell, 2020)	CRE's operational model will continue to undergo a transformation, shifting from solely being agile to be able to facilitate the adaptive future-ready enterprise. Digital technologies will be implemented to create smarter, intuitive and personalised working environments in order to augment people's ability to work effectively.
Purpose of Place - History and Future of the Office (Cushman & Wakefield, 2020b)	5 dynamics for the future of office: Productivity & Output; Innovation & Creativity; Company Culture & Branding; Employee Satisfaction & Retention; Location & Building Strategy.
Reimagine - The new future of work to shape a better world (JLL, 2021b)	Enterprises are more focused on their #1 investment: people. The new workplace purposes shall be Health & Well-being; Employee Engagement Experience; Culture & Pride in Belonging; Learn & Socialize Innovate; and Brand Experience.
COVID-19 Global Real Estate Implications Paper II (JLL, 2020b)	In the post-pandemic worlds, megatrends will continue to evolve - growth in corporate outsourcing; rising capital allocations to real estate; urbanisation; technology; sustainability.
EMEA Office Markets Update – The Current State of Play | Opportunities and Risks on the Road Ahead [Webinar] (Colliers, 2020)	It is suggested that there will be a higher demand for flexibility across portfolios in the future. *Increased demand for flexibility in traditional office leases, increased demand for flexible workspace and coworking solutions,* and *increased demand for space in newer, sustainable, high-quality buildings with compelling tenant amenit*ies are the three most acknowledged primary impacts of the COVID-19 pandemic to future demand for office space. The biggest changes should be made to traditional offices to enable the work in future are recognized as HR policies that support flexible and dynamic working, and conference and meeting room technology to accommodate in-person and remote participants.
Healthy workplaces: what we know and what else we need to know (Jensen & van der Voordt, 2019)	Apart from particular influencing factors that influence Healthy Workplaces (HWs), such as plants, light setting and indoor climate, various papers also show that spatial layout, especially the level of openness and environment for communication, concentration and privacy, and interior design have a great impact on HWs.
Health and Wellbeing in Modern Office Layouts: The Case of Agile Workspaces in Green Buildings (Laughton & Thatcher, 2019)	***ABW*** as a less territorial space that supports the requirements of tasks, and ***private enclosed workspace*** give the end-users **higher** comfort regarding physical and psychological health **than *open-plan office space*** that represents co-located and segmented individual workstations. This is because ABW (agile workspaces) allow employees to gain the control over the environment they want as the workspace is unassigned but reservable.
Smart work: Supporting employees' flexibility through ICT, HR practices and office layout (Raguseo et al., 2016)	The results showed that there is complementarity between the elements that characterise the Smart working (SW) model, and at least two elements are developed in each SW model. If these three factors are all developed, enterprises will achieve higher productivity. These three elements are ICT, HR and workplace layout.

Source	Major findings
	A complete SW implementation should include all of these three elements. In other words, SW corresponds to a work practice, which is characterized by flexibility in space and time, supported by technical tools, and provides the best working conditions for all employees of the organization to complete tasks. To achieve a successful SW implementation, the common effort of ICT, HR and CRE departments is needed.

Table 4.2.4 Summary of smart building

Smart building solutions is technology that is implemented in the workplace to help with health & well-being service, sustainability control, strategic space management, etc (Colliers, 2020; Jensen & van der Voordt, 2019; JLL, 2021a, 2021b). For example, smart booking system as a smart building solution can help improve resource management and strategic space management. Personalised environmental control can improve health and well-being service. Inter-disciplinary collaboration between corporate real estate, facilities management and human resources departments, with employees' involvement, has been fundamental to establish (Raguseo et al., 2016; Tagliaro & Ciaramella, 2016).

Successful implementation of smarting building solutions can positively help with ABW implementation in terms of decreasing the need for space, as smart building solutions can optimise the space use especially regarding meeting rooms and collaboration space (Colliers, 2020; Laughton & Thatcher, 2019). It also helps to optimise the desk occupancy rate, for example, real-time monitoring of the occupancy can be achieved and it can monitor employees' chosen days to go to the office thus avoiding a huge peak day during the week.

4.2.4 Proposed office space demand forecasting formula and the output of steps 2-5 of proposed scenario planning methodology

As stated at the beginning of section 4.2, this sub-section answers sub-question 2 and also completes steps 2-5 of the proposed scenario planning methodology.

Proposed office space demand forecasting formula

Sub-question 2 is answered by proposing this formula. Based on the literature study of possible future trends of CRE office workplace, a suitable formula for post-pandemic office space demand forecast at a corporate level is proposed:

$$D = \sum \Delta D = \sum \Delta\gamma \times \Delta\beta \times \Delta\theta$$

Where:

D = Total demand of office space
γ = **ABW implementation plan**
β = **1/share-ratio**
θ = The **employment headcount** classified by different employee groups

ABW implementation plan consists of the kinds of seats that should be implemented, the proportion of every certain kind of seat and the area that every certain kind of seat needs.

Share-ratio is dependent on two independent variables: average number of days employees work in the office in a week, and desk occupancy rate. ***Employment structure*** classifies employees by personal requirements and work-related activity types, thus indicating the employee headcount of each group.

Outputs of steps 2-5 of the proposed scenario planning methodology

Step 2: Identifying key indicators

The key indicators are the independent variables in the formula, which are: ***(1) ABW implementation plan, (2) the average number of days employee work in the office (or WFH) in a week, (3) desk occupancy rate,*** and ***(4) employment structure.***

Step 3-5: Identifying possible future trends, identifying impacts of trends on trends and key indicators. And establishing cross-impact analysis model

After the literature study, the conceptual CIA model that is used to create scenarios can be presented below (Figure 4.2.2). This model illustrates the key indicators, possible future trends, and their intertwined impacts.

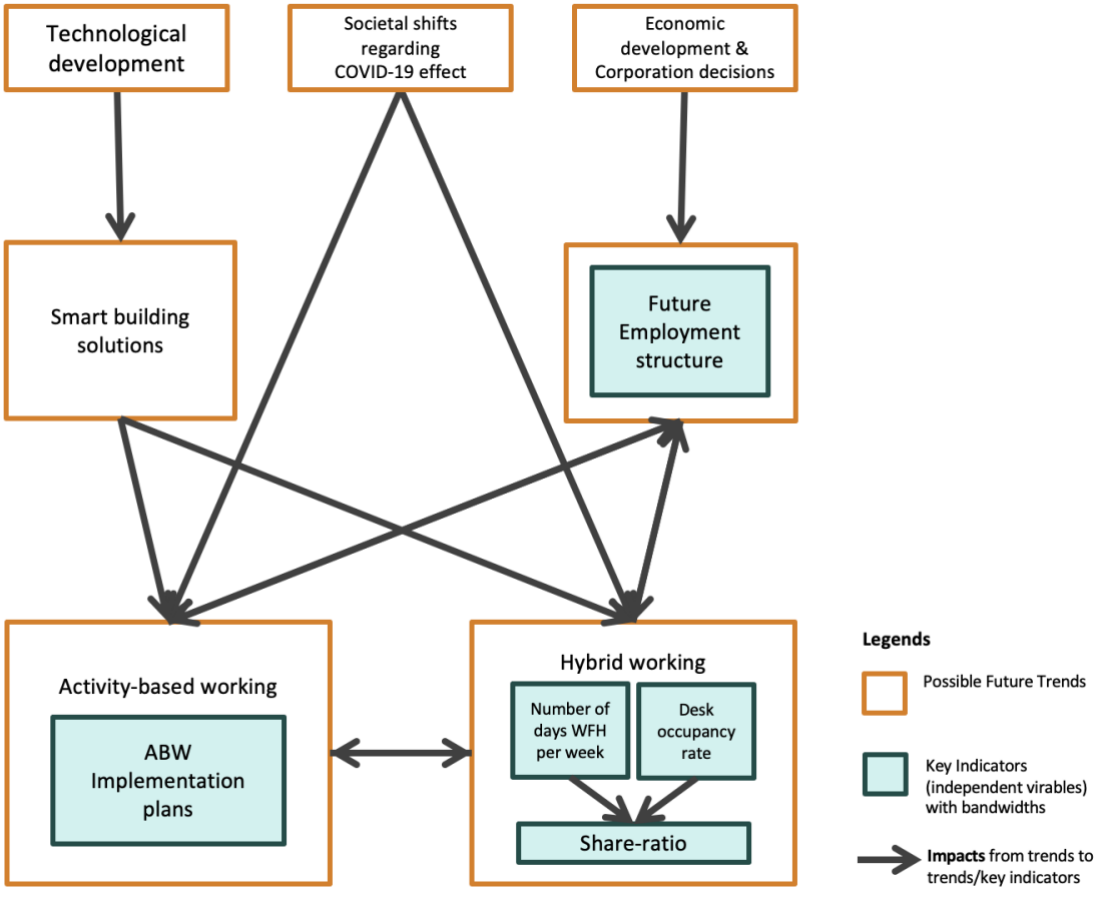


Figure 4.2.2 Updated CIA model (Own illustration)

5 Pilot study

Due to the Embargo agreement, this chapter will not become public.

The pilot study is to answer sub-question 3: *How can the proposed scenario planning methodology and office space demand forecasting formula be applied for corporate real estate?* In the design process cycle, answering sub-question 3 is to realise the design to solve the problem.

To answer this question, the steps of the proposed scenario planning methodology are taken to conduct the pilot study. By selecting the pilot, step 1 'defining the issue and time period of analysis' is finished. This is done in section 5.1.

Steps 2-5 are finished at a generic level in chapter 4. The corresponding outputs can be used in this pilot. Because the pilot case is post-pandemic office space demand scenario planning in Philips Center, Amsterdam, and the outputs of steps 2-5 has a scope of post-pandemic office space demand at a corporation level in the Netherlands. The pilot study fits in this scope. Therefore, the pilot study uses the outputs of steps 2-5 that are finished in chapter 4.

Step 6 'Developing initial scenarios by 2x2 matrix approach or morphological analysis' is finished in section 5.2. Step 7 'projecting bandwidths of key indicators' is finished in section 5.3. Step 8 'preparing office space demand forecasts' is finished in section 5.4.

Step 9 'studying implications' refers to evaluating business strategies based on scenarios. Yet the pilot study is to 'pre-test' a particular instrument (Van Teijlingen & Hundley, 2001), an expert panel to examine the replicability and validities of the proposed methodology is conducted instead of focusing on business strategy evaluation to study the implications. The expert panel and the interview regarding PACT model provide the content of discussion on the findings, this part is therefore put in chapter 6 instead of chapter 5.

The whole chapter 5 shows how can the proposed methodology and formula be applied for CRE including indicating how research approaches are conducted to finish the steps.

In the formal science process (Barendse et al., 2012), the pilot study is to 'realise/use' the calibrated design. Conducting a pilot study complies with the design science research cycles (Hevner, 2007) as the pilot study is about 'applying the proposed methodology to a case' and 'evaluating the replicability and validity of the proposed methodology'. The design (proposed methodology) is applied in the application domain and in return contribute to the knowledge base.

Relating these steps to the research design, it can be found that these steps are conducted by different research methods. The relation is presented in Figure 5.1.1.

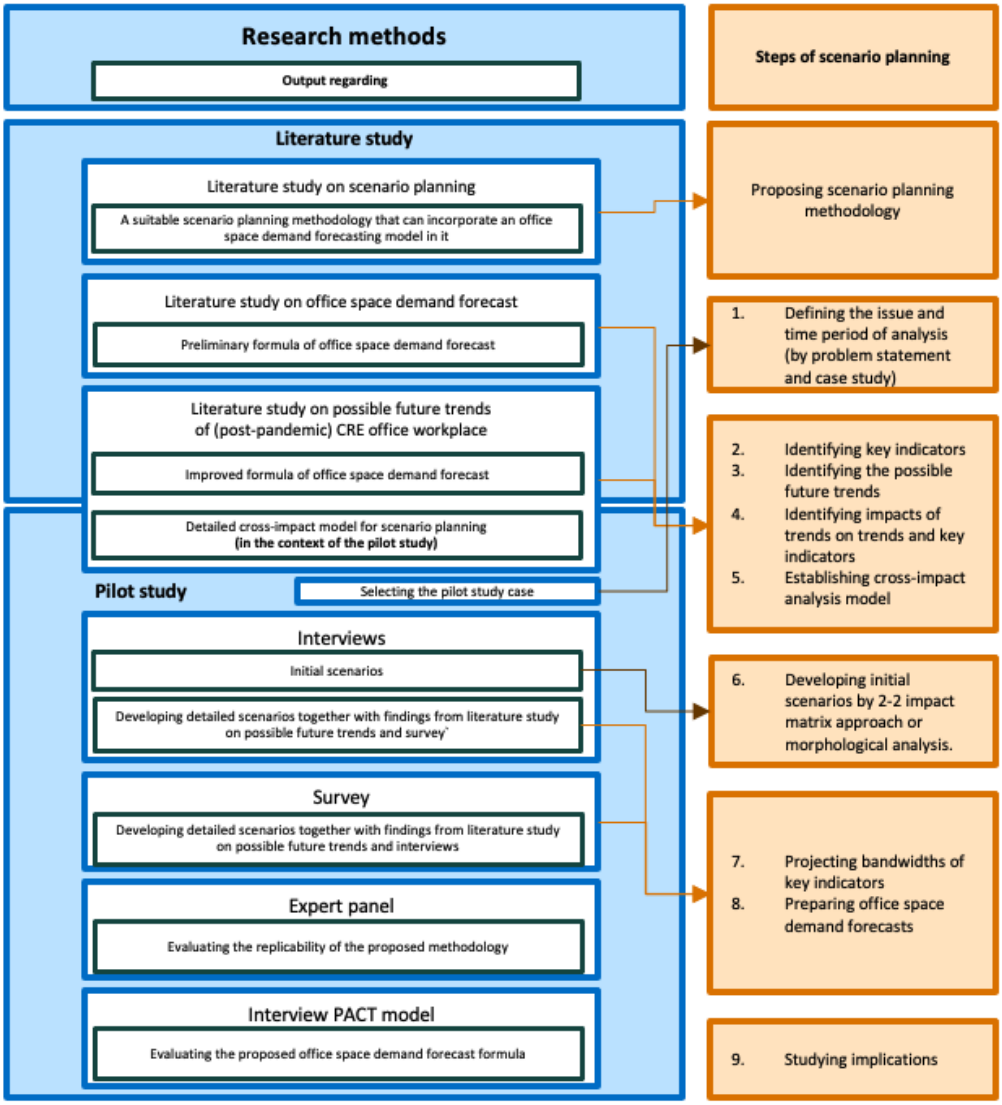


Figure 4.2.1 Relating research methods to scenario generation steps (Own illustration)

6 Clash analysis

Due to the Embargo agreement, the first two sections of this chapter will not become public.

This chapter analysis the 'clash' after the design is realised. As indicated in the design process cycle, a clash may emerge after the design is realised. This means that the design may be improved to solve the 'problem' in the design process cycle. The clash in this research are about the possible improvement and limitations of the proposed scenario planning methodology and the proposed office space demand forecasting formula. To evaluate the proposed scenario planning methodology, an expert panel is conducted; to evaluate the proposed office space demand forecasting formula, an interview to understand an existing office space demand forecasting model (PACT model) is conducted. By conducting the clash analysis, the replicability, external validity, internal validity and measurement validity can be evaluated.

6.1 Expert panel

6.2 Interview PACT model

6.3 Research evaluations

This section discusses the replicability and validities of certain findings of the research. Bryman (2016) indicated three of the most prominent criteria for the evaluation of social research, namely ***reliability***, ***replicability,*** and ***validity***. ***Reliability*** concerns the extent to which a research instrument is stable or not – whether it consistently provides the same results if it is conducted repeatedly in the same situation (Bryman, 2016). As the research methods in this thesis do not have the same concern, this criterion is therefore excluded from evaluations. The evaluations focused on ***replicability*** and ***validity***.

Replicability

Replicability means the possible ability to replicate the research findings to others (Bryman, 2016). A study must be replicable for replication to take place (Bryman, 2016). The focus of replicability in this research lies in the proposed methodology. In terms of the methodology of scenario planning that provides quantitative outputs of office space demand estimates, the replicability is acknowledged in the expert panel – the research of developing scenarios with office space demand estimates in other scopes can be conducted by using the same methodology. It is notable that only the methodology per se can be replicated, while the CIA model or the office space demand model cannot, because the trends and key indicators may

differ in different scopes. Therefore, the scenario planning steps (Table 3.3.2) has replicability. Yet the comprehensive version of the proposed methodology has very limited replicability, it may be applied only to similar properties to Philips Center, such as the High Tech Campus of Philips in Eindhoven. The findings regarding the scenario outputs in the pilot study, however, do not have replicability.

External validity

External validity is concerned with the question of 'whether the results of a study can be generalised beyond the specific context' (Bryman, 2016, p.42). The external validity of proposed methodology and the proposed office space demand forecasting model is examined.

Regarding the proposed methodology, the author suggests that the methodology can be generalised to the scope of 'scenarios with office space demand estimates' without focusing on 'post-pandemic'. Because it is found that pandemic only impacts the possible future trends, it does not affect the methodology of scenario planning. In a wider context, the proposed methodology is still applicable. It is notable that possible future trends may differ in different contexts, yet this does not interfere the proposed steps of scenario planning.

The author also suggests that proposed steps of scenario planning (answer to sub-question 1) may even be applied to a wider scope that is not related to 'office space demand'. As long as the quantitative output is needed from the scenarios, and key indicators, which can derive or directly represent the desired quantitative output, can be identified. The proposed steps of scenario planning can be applied. For example, if a formula of carbon footprint forecasting can be developed, it can be incorporated into the proposed scenario planning methodology (answer to sub-question 1). It is possible that carbon footprint scenarios can be developed.

However, the external validity of the the proposed office space demand forecasting model is low. In the interview regarding the PACT model, it is found that certain flaws exist in the current proposed model. The flaw regarding the *potential conflict of ABW and hybrid working needs* and *occupancy rate* to be fixed, as potential deviation of the office space demand result already emerges in the pilot study. The flaw of the task groups and persona groups not clearly illustrating the activity patterns needs to be fixed, otherwise the model cannot be generalised and used outside the scope of Philips' CRE.

Internal validity

Internal validity is concerned with the question of whether the causal relationship between two variables is reasonable (Bryman, 2016). In this thesis, findings regarding the analysis of the proposed CIA model, the construction of a 2x2 matrix, and initial (qualitative) scenarios are examined in the expert panel to evaluate the internal validity. Panellists acknowledged all mentioned findings while considering the context of the pilot study case. This means that the internal validity in terms of the identified causal relationships in this research are proven.

However, the author noticed that the two clustered trends that are identified in the pilot study case – employees' adaptation of conducting hybrid working and ABW and corporation's performance of implementing and applying technology in the office – are both fundamentally

internal. External trends such as marcoeconomics development, industry growth, etc, are not mentioned during the interviews. This may be because interviewees are not specialists in such fields, they are not able to give credible information regarding these topics, and the invitees in the expert panel are not specialists in the mentioned fields either. Therefore, it is possible that some causalities or trends are not identified in the scenario planning process.

Measurement validity

Measurement validity is to do with the question of 'whether a measure that is devised for a concept does reflect the concept that it is supposed to be denoting' (Bryman, 2016). The FoW survey and the bandwidths of key indicators are examined during the expert panel. The modification of code used for data analysis of the FoW survey was exanimated during the internship process. Panellists confirmed the measurement validity of all mentioned research data and findings. Experts confirmed the correctness of the programming code used for data analysis.

To conclude this section, due to the fact that certain findings in this research do not apply to certain criteria of evaluating the research. The findings are evaluated respectively regarding different criteria. Through the expert panel, consultations during the internship, and the interview regarding the PACT model, the replicability and validities of different aspects of findings in this research are explained.

7 Conclusion and Discussion

This chapter presents the conclusion and discussion of the whole research. Research questions are answered to draw the conclusion in section 7.1. The added value and research implications are discussed by comparing research findings to existing knowledge in section 7.2. Research limitations, and recommendations are respectively presented in sections 7.3, and 7.4.

7.1 Research conclusions

To conclude the research in this section, research sub-questions are sequentially answered, and the main research question is answered at last.

Research sub-question 1

What is a suitable methodology of scenario planning that can develop quantitative office space demand scenarios on the corporate level?

Through literature study, it is decided that a suitable methodology can be developed based on a methodology named INTERAX and further modified. The steps of the proposed suitable scenario planning methodology are presented below in Table 7.1.1.

Scenario generation steps	
The topic	1. Defining the issue and time period of analysis
Key decision	2. Identifying key indicators
Influencing factors	3. Identifying the possible future trends
Cross-impact analysis	4. Identifying impacts of trends on trends and key indicators 5. Establishing the cross-impact analysis model
Initial scenarios	6. Developing initial scenarios by 2x2 impact matrix approach or morphological analysis.
Detailed scenarios	7. Projecting bandwidths of key indicators 8. Preparing office space demand forecasts
Implications	9. Studying implications

Table 7.1.1 Scenario generation steps (Own illustration)

In essence, to make a scenario planning methodology suitable for developing quantitative office space demand scenarios on the corporate level, a mathematical formula of office space demand forecasting needs to be incorporated into the methodology. In this formula, certain independent variables together result in the dependent variable – office space demand.

The detailed scenarios should be equipped with all the values of independent variables. With a set of values of independent variables in a scenario, the formula of office space demand forecast has its inputs, the total office space demand can then be calculated. Thus, each scenario has its own value of total office space demand.

These independent variables are also called 'key indicators' in scenarios. As these key indicators' values are parts of the quantitative outputs of the scenarios (the other part is the office space demand), the process of scenario planning is about projecting these values for scenarios. Therefore, the key indicators need to be identified at the early stage of scenario planning, and the scenario planning methodology needs to adopt an outcome orientation method.

After defining the research scope of the scenarios (step 1) and identifying key indicators (step 2), possible future trends should be identified through research (step 3). The causalities between the trends and key indicators should also be identified (step 4). In most scenario planning cases, these causalities are intertwined and complicated. A cross-impact model that illustrates the impacts of trends on trends and trends on key indicators needs to be established (step 5). A conceptual example of CIA model is presented below in figure 7.1.1.

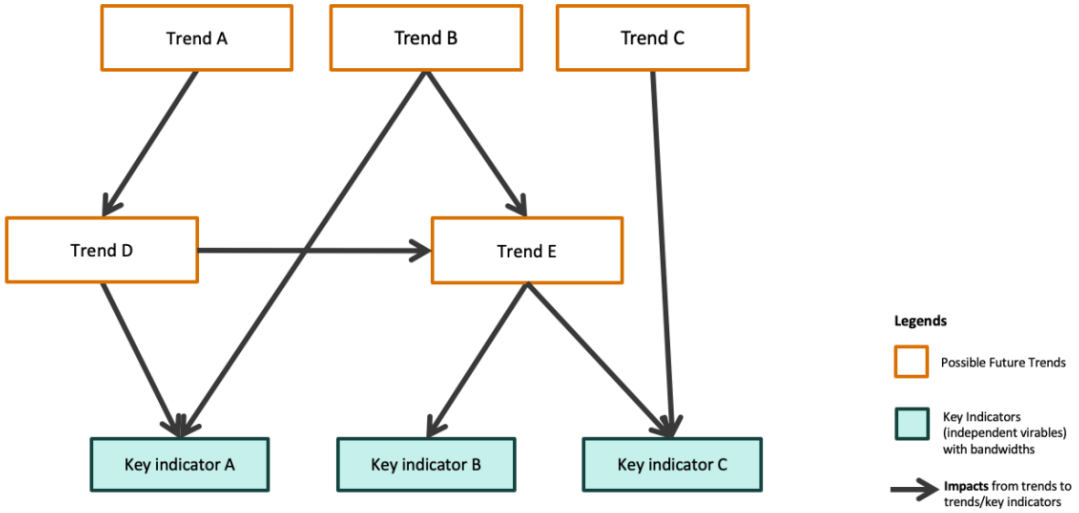


Figure 7.1.1 Conceptual CIA model (Own illustration)

The next step is to examine the predictabilities, impact levels, and possible consistencies of the trends. The trends can then be clustered. In different scopes, developing scenarios can be done through 2x2 matrix approach or morphological analysis approach (step 6). If the overview of trends reveals that the two most uncertain clustered trends are enough to develop scenarios, the 2x2 matrix approach should be taken, otherwise, the morphological analysis should be adopted. What's more, if extensive research is feasible, a comprehensive cross-impact analysis approach can be conducted to explore the probabilities of occurrences of trends, thus the scenarios are developed with possibilities of their occurrences. Due to the limitation of this master thesis, the last approach is excluded from the suggested approaches in step 6. All three approaches are introduced in section 3.3.

After initial scenarios developed, the next steps are to project the bandwidths of key indicators (independent variables) (step 7), assign values from bandwidths to each scenario and use these values to prepare office space demand forecast (step 8). The last step is to study the implication and evaluate strategies based on the scenarios (step 9).

Research sub-question 2

What is a suitable mathematical formula of office space demand forecasting for corporate real estate in the post-pandemic context?

As explained in the answer to sub-question 1, a formula of office space demand forecasting needs to be proposed. As the scope of scenarios in this research is the future of CRE office in post-pandemic era, the office space demand needs to be forecasted at one specific time rather than an interval of time, and it needs to be considered that post-pandemic CRE office workplace trends may affect the formula. Through the literature study, a stock model with consideration of post-pandemic CRE trends is proposed based on the logic of disaggregated demand model:

$$D = \sum \Delta D = \sum \Delta\gamma \times \Delta\beta \times \Delta\theta$$

Where:

D = Total demand of office space
γ = **ABW implementation plan**
β = **1/share-ratio**
θ = The **employment headcount** classified by different employee groups

The formula follows a very simple logic, that is, *the total office space equals to the sum of space needed per user*. Under this logic, the formula is enhanced as a disaggregated demand model that classifies users and differentiates the space demands of different user groups.

In this formula, the independent variables (key indicators) are ***(1) ABW implementation plan, (2) the average number of days employees work in the office (or WFH) in a week, (3) desk occupancy rate,*** and ***(4) employment structure.*** The fourth one is represented by θ in the formula. The second and third one together result in the change of β. The first one is represented by γ.

Employment structure classifies employees based on their *work-related activity types* and *personal needs and requirements*. The two classifications are called ***task groups*** and ***persona groups***. The employees are classified in this structure because ABW implementation plans and share-ratios need to be customised to fit different working activities and personal needs of employees within an organisation. The ***employment headcount θ*** per group is derived through the classification.

Share-ratio (1/β) is the ratio of the *number of employees to the number of seats*[8]. The share-ratios firstly differ between different persona groups based on users' preference and needs of conducting ABW, they are then modified based on the ***average number of days employees work in the office (or WFH) in a week*** and ***desk occupancy rate.***

The modified share-ratio is $\frac{5\delta * \eta}{\alpha}$.

Where:

δ = share-ratio (sheerly based on ABW, differs per persona group)
α = number of days employees working in the office in a week,
η = desk occupancy rate
($0< \alpha \leq 5$, $0< \eta \leq 100\%$)

ABW implementation plans differ between different ***task groups***. It concerns the number of seats the office needs, the kinds of seats (work-settings) that should be implemented, the proportion of every certain kind of seat and the area that every certain kind of seat needs. ***ABW implementation plan γ*** is presented as a form that presents the percentages of amounts of work-settings to the total seat count. Through the share-ratio and employment headcount, the total seat count needed per employment group can be derived. After deriving the total seat count per task group, the number of different work-settings can be derived.

The values of these four key indicators (may) differ in different scenarios, thus the results of the total office space demand are also different in different scenarios.

In conclusion, a suitable mathematical formula of office space demand forecast for CRE is presented above. It is regarded as a suitable formula because the independent variables in the formula can theoretically calculate the office space demand, and they are able to be fitted into the proposed scenario planning methodology. This formula is incorporated into the proposed scenario planning methodology indicated in sub-question 1.

Research sub-question 3

How can the proposed scenario planning methodology and office space demand forecasting formula be applied for corporate real estate?

To apply the proposed scenario planning methodology and office space demand forecast formula, the formula in sub-question 2 is incorporated in the methodology in sub-question 1. The proposed methodology is applied in the pilot study by following its steps.

During the pilot study, extensive research needs to be done to conduct these steps. The chosen pilot determines the scope of scenario planning to finish step 1. The literature study in section 4.2 regarding possible future trends of CRE office workplace finishes steps 2-5: The key indicators and possible future trends are identified, and the cross-impact analysis model is established. Step 6 'developing initial scenarios' is done by examining and analysing the CIA

[8] The **seats** mean individual workplace desks. It does not include the seats in collaboration space, meeting rooms, etc.

model through semi-structured interviews. Step 7 'projecting bandwidths of key indicators' and step 8 'preparing office space demand forecasts' are finished based on data analytics of surveys that investigates employees' behaviours and perceptions, interviews with relevant stakeholders and literature study. After detailed scenarios are developed in step 8, implications of the scenarios can be studied to finish step 9.

After proper analysis of the pilot study, the proposed methodology is applied to a real case for CRE. The scenario outputs are presented in sub-section 5.2.3 and section 5.4. After discussion regarding the scenario output findings in the expert panel, and examination of relevant market research of post-pandemic office real estate, it is considered that the scenario outputs in the pilot study have internal validity and measurement validity.

Main research question

How can scenario planning give quantitative output on post-pandemic office space demand for corporate real estate?

The three sub-questions together form the answer to the main question. Based on the whole research, it is found that by applying the proposed scenario planning methodology, scenario planning ***can*** give quantitative output on (post-pandemic) office space demand for corporate real estate. After the application, scenarios with quantitative office space demand are developed.

The proposed methodology that incorporates the proposed formula can be applied in certain scopes. The criteria of the scopes are: (1) the to-be-developed scenarios are about office space demand at a corporate level, it can be applied to one property, or several properties within one organisation at once if they face the same (low predictable) external strategic environment; (2) the organisation's internal data that is required for research has high reliability, or high reliable internal data can be analysed through research.

Notably, ***(1)*** the CIA model, along with the trends analysis that is developed in this thesis cannot be replicated to other scopes, this is because the trends may differ in different scopes. For example, an organisation that intends to change its operation strategy may have to consider possible future trends about its industry development; ***(2)*** the proposed office space demand forecasting formula (model) has certain flaws, in order to apply it to other scopes, modifications of the formula (model) are required. The model needs to be modified in terms of (i) the potential double count of the time spent on WFH during the share-ratio computation process; (ii) the potential change of activity patterns in the office when the time spend on WFH changes; (iii) establishing the activity pattern (the time spent on different tasks) and incorporating it into the ABW implementation plan making process; and (iv) incorporating quantitative research on desk occupancy to compute occupancy rate; ***(3)*** the key indicators and the employee classifications need to be evaluated in each scope, this is because every CRE is different and there is no universally applicable set of key indicators or employee classification groups.

In order words, the proposed scenario planning methodology per se (the answer to sub-question 1) is applicable and does not need modification. However, it is not an easy-to-

operate tool because extensive research needs to be conduct to apply this methodology. The CIA model, including the identification of key indicators and possible future trends, differs in each different scope. Regarding the office space demand forecasting model, modifications need to be done because of two reasons: (1) the key indicators (independent variables) which construct the formula differ in different scopes; and (2) the proposed office space demand forecasting model has certain flaws and needs to be improved.

As there are potential flaws in the current proposed office space demand foreacasting model, the design process cycle of operations research needs to be iterated till there is no 'clash' – the model per se has no flaws.

In conclusion, different scenarios will be developed when applying the proposed scenario planning methodology in different scopes. While the same methodology can be applied to different scopes, specific research must be done to apply the methodology and develop credible outputs.

7.2 Added values and research implications

This section discusses the added value and research implications by relating findings to existing knowledge. Findings of the scenario planning methodology and office space demand forecasting formula are concluded in section 7.1, they provide the added value of this research. Findings of the scenario outputs are presented in chapter 5, they are related to findings from scientific literature and commercial papers to discuss the implications.

Added values

In this research, the proposed scenario planning methodology incorporates an office space demand forecasting formula. It basically means that, instead of directly projecting the 'office space demand' in the scenario planning process, it is broken down into several indicators, and the values of these indicators are projected. While the demand per se is hard to be directly projected, projecting these indicators are relatively easier.

The proposed methodology is built upon INTERAX approach from PMT (Probabilistic modified trends) school. Scenario planning methodology research by Bradfield et al., (2005), Pilkahn (2008), and Amer et al., (2013) are examined and used to build up and propose the methodology. The proposed methodology does not concern 'probability' – scenarios developed by this methodology are not assigned with probabilities of occurrences. This is, however, acceptable. Because this research only intends to propose a methodology that develops scenarios with quantitative descriptions of office space demand, but not scenarios with probabilities of occurrences. In other words, the scenarios developed in the proposed methodology are not assigned with probabilities of their occurences.

As an operations research, the added value of this thesis is that a scenario planning methodology that incorporates an office space demand forecast is proposed. To the author's knowledge, there is no comprehensive explanation of how scenario planning methodology can be applied to develop quantitative office space demand scenarios at a corporate level in

scientific papers, and the methodology proposed in this thesis fills this research gap. Notably, the proposed methodology is only applied in one pilot case. The proposed scenario planning methodology, the proposed office space demand forecasting model and the research methods that are adopted can be improved by further research.

Research implications

As for initial scenarios, the two clustered trends (uncertainties) that are identified to develop the scenarios are *(1) corporation's performance of implementing and applying technology in the office, and (2) employees' adaptation of conducting ABW and hybrid working.* Study shows that the three major impacts of COVID-19 on CRE workplace in the Netherlands are (1) impact on corporations in terms of their business strategies, (2) impact on individuals (office users), and (3) impact on top management in terms of their decision making, attitude towards workplace, and compliance with guidelines (Hou et al., 2021). These impacts come from the low predictable external strategic environment (the COVID-19 pandemic), while the existence of these impacts is real, how the impacts will develop are uncertain. By comparing these impacts and the clustered uncertainties in this research, it can be identified that they are somewhat aligned: *corporation's performance* reflects *the impact on top management*; *employees' adaptation* reflects *the impact on individuals*. The impact on corporations in terms of their business strategies is *not* reflected in the clustered uncertainties in this research, this is because, through the interviews in the pilot study, it is identified that the impact on the corporation's (Philips) business strategies is not significant. As the scenarios developed in this research is specifically for the pilot case, it is reasonable that not all uncertainties identified in the scientific paper fit in in a certain case.

All scenarios indicate that less office space is needed in the post-pandemic era. This is consistent with findings in scientific literature and commercial papers. Hou et al., (2021) stated that the pandemic enables WFH's wide acceptability and existence in the foreseeable future, which leads to 'structurally less use of space'.

As the scenarios' outputs indicate, the post-pandemic office space demand in 5 years is 2% - 34% lower than the current office space area that Philips has at its disposal. While there is no research regarding the (mis)match between the current office space area and pre-pandemic demand, the outputs only reveal that the future office footprint will be 2% - 34% lower than the current situation.

Scientific literature and various commercial papers indicated that there will be a decline in post-pandemic office space demand (Cushman & Wakefield, 2020a; JLL, 2020, 2021b; Naor et al., 2021). Cushman & Wakefield (2020a) predicts that the European office demand is expected to be 17.4% lower from 2022 to 2030 at its baseline (most probable) scenarios, this stands at the median of the projected office footprint reduction bandwidth in this thesis. Notably, although the findings from the commercial paper and findings of this research seem to align, the forecast outputs at a regional level and a corporate level do not have to be exactly the same, as different factors are considered in different scopes: at corporate levels, the factors considered are mainly ABW and hybrid working; while at regional levels, the factors that are considered are mainly job growth and hybrid working (Cushman & Wakefield, 2020a).

It is also found that 74% of the Fortune 500 companies expect a reduction of the office space in the post-pandemic era, for example, HSBC plans to reduce 40% of its office space (Fortune, 2021; Reuters, 2021). Although these strategies are not identified in scientific papers and corporations' office footprint strategies may differ, they showed that most corporations do have the same prediction, that is, there will be (sometimes a substantial) reduction of their office space. It can be presumed that these corporations have done their research to develop such predictions, yet their predictions and corresponding strategies are not revealed due to confidentiality reasons.

Nevertheless, the findings of the scenario outputs in this research do agree with scientific papers and commercial papers, post-pandemic office space demand is expected to decrease. To a certain extent, this proves that the proposed methodology can be applied to provide plausible scenarios that may happen in the future.

7.3 Research limitations

No research is perfect – limitations exist in every research. Clarifying and acknowledging the limitations in the research allow researchers to better understand the research and make improvements in future studies.

The limitation in research methodology

In this operations research, the research methods that are taken are literature study and pilot study, the latter contains a survey and corresponding data analytics, interviews with internal specialists of the case, expert panel and an external interview regarding an existing office space demand forecasting model. The expert panal and the external interview are conducted after the application of the methodology in the pilot study case.

It is considered that the pilot study may be replaced by multiple-case holistic case study. This will allow the proposed methodology to be applied in different cases with different contexts, which will help construct replicability and external validity of the research findings. Also, the proposed office space demand forecasting model in this research adopted details of an existing model of Philips. While without which the pilot study cannot be conducted, the details that are adopted or modificated and used for the forecasting model limits the possibility of hypothetically applying the model outside the context of Philips. If a multiple-case case study was conducted, the model may be improved during the proposing phase so that it can be applied to scopes outside the pilot study case without modification.

The completeness of literature study

Scientific papers are acquired only from the database of Scopus. Commercial reports are required by manual search in Google and webpage of certain companies. Relevant papers and reports may have been missed. Keywords used for searching were carefully examined and defined, yet certain research may have used different keywords. Because of this,

methodologies of scenario planning and office space demand forecast may have not been thoroughly examined and analysed. The proposed methodology of scenario planning and demand forecast may be improved. The proposed CIA model may have missed some key possible future trends. This may affect the replicability and external validity of the proposed methodology in the research as defined by Bryman (2016).

For example, it was at the end of the research when the author found that there exists the practice of developing CRE office space demand forecast model while incorporating scenarios. After carefully examining the research, it is found that there is a fundamental difference between the model developed by CfPB (de Bruyne & Beijer, 2015) and the methodology developed in this research. The former one examines office space demand by establishing an office space demand model named PACT, the 'scenario calculation' is inputting altered values in the model without holistic research of scenario planning – in order words, scenario calculation in the PACT model is adopted 'as an additional exercise' (de Bruyne & Beijer, 2015, p. 130) and the so-called scenarios lack plausibility. While in this research, the office space demand was examined initially by developing plausible quantitative scenarios. Nevertheless, these two research have similarities and a stronger argument could have been built in the problem statement and literature study.

Data collection and analytics of the survey

The survey was not prepared by the researcher. Although the dataset from the survey is proven to be sufficient for this research. Certain questions may be better phrased or even modified to gain more reliable data. For example, the answer options of question 7 in the FoW survey was not formulated properly: when the respondents are asked 'how much time did you spend on the following tasks pre-COVID', the sum of their time spent on all four tasks can exceed 100%, although the answers are normalised (as explained in sub-section 5.3.1), the survey system should be designed to only allow respondents to reply with answers that together sum up to 100%.

When dealing with the growth and decline bandwidth of the total headcount of personnel, the data analysis results and bandwidths are also simply extrapolated to the final headcount. This might not be correct as a certain decline or growth of people can be of certain tasks/persona groups, such decline or growth is ignored in this research Thus, the values of certain key indicators cannot be directly extrapolated to the adjusted personnel. This issue may only be solved with the help of more advanced data analysis such as machine learning that automates analytical model building.

It also comes to mind that the fact that the survey was conducted in October 2020 may create certain issues – employees' perceptions may have changed due to a more profound impact of the pandemic since October 2020 till the research is finished, this can cause changes in data analysis results, thus further changing the research findings. This may have affected the reliability of the research. However, the author suggests that this is a relatively less important issue because the development of bandwidths helped to lessen this negative effect. And as for the scope of this thesis, the later the survey is conducted, the more 'reliable' the results are. There can be no 'most reliable' results in this sense.

Confidentiality-related issue during data collection of interviews and expert panel

Due to confidentiality issue, Philips's data cannot be shared outside of Philips. The interviewees and panellists from the expert panel were chosen from relevant experts within the organisation of Philips. Although they have extensive experience and knowledge regarding CRE and workplace solutions, their answers in interviews and the expert panel may have biases, for example, interviewees may be overconfident when thinking about the highest achievable desk occupancy rate. Such partialities may affect the analysis of trends and development of bandwidths, thus affect the internal and external validity of the research as defined by Bryman (2016).

Hypothetically, if the interviewees and panellists can also be experts outside of the organisation, and there are no repeated invitees in interviews and the expert panel, the research findings may have higher credibility and validity.

The interview regarding the PACT model is conducted at last to examine the proposed office space demand forecasting model. Although the proposed model was not shared with the interviewee, it is found that some flaws do exist in the proposed model, this further proves that it would be better if external opinions can be included during the methodology construction and application process.

7.4 Recommendations

This section presents recommendations for future research and practice. The recommendation is based on research findings, conclusions, limitations, author's experience from data analytics of the survey, and feedback from interviews and expert panel.

7.4.1 Recommendation for future research

Strengthening the methodology of scenario planning

The proposed methodology suggests conducting a 2x2 matrix approach or morphological analysis to develop initial scenarios. However, another approach that takes more effort – a comprehensive cross-impact analysis is mentioned yet abandoned in the methodology. This is because it requires huge effort yet still has its limitations as indicated in section 3.3. Nevertheless, it is valuable to further research on the feasibility and steerability of incorporating this approach to develop scenarios.

By conducting comprehensive cross-impact analysis, the probabilities of occurrences of trends shall be identified, thus the scenarios shall be equipped with probabilities of their occurrences through Monte-Carlo simulation. This can further portray the scenarios.

More in-depth research on ABW and its implementation plan

The ABW implementation plan in this research took heavy support from the information given by Philips. It is credible in the scope of Philips – as the Philips's FoW research has been conducting all over the world and all local teams gave positive feedback regarding the credibility and feasibility of the ABW implementation plan. However, the author's own research on ABW in this thesis stays merely on the qualitative side. To develop a holistic office space demand forecast, quantitative research is needed.

The same suggestion applies to the pre-defined share-ratios and employment structure classification in the scope of ABW. The author's own research only touched the surface of the quantitative side alongside the qualitative side. Although the modification was done and approved, the fundamental quantitative data was taken from Philips. Again, the information worked in Philips, yet to *hypothetically* apply the methodology in other scope, quantitative research that applies to a more general scope (outside Philips) is needed.

More in-depth data analysis – machine learning

As mentioned in limitations, the current programming code of data analysis is not resilient enough. It cannot solve the data quality issue while simply extrapolating the data analysis results from respondents to total personnel, nor can it cope with the situation when the personnel is experiencing a major shift of a relatively single group of personnel – for example, a sudden growth or decline of a certain department. Because the employment structure in a certain department may be different from that of the whole property, one simply cannot extrapolate the results from data analysis to heavily shifted personnel. This issue is more obvious when dealing with the total headcount shift in detailed scenarios.

To solve this issue, more in-depth research by machine learning can be conducted. Machine learning is an artificial-intelligence-based method of data analysis that automates analytical model building (Wikipedia, 2021b). The proper research of machine learning can help the programme to identify and classify the personnel in a smarter way, thus making the results of data analysis more credible.

Research regarding future personnel change

The future personnel change per se can be another totally different scenario planning research. As indicated in the interviews and expert panel, the factors of which are too many to be examined in the scope of this thesis. If the research of future personnel shift is done, it can be incorporated into this research to develop more holistic scenarios.

The research regarding future personnel shift can also be incorporated into the previously mentioned research regarding machine learning. As the system of machine learning learns from data, it can identify patterns of respondents (data) and therefore make better decisions of employment structure while considering the personnel shifts of departments and headcount. Together they can undoubtfully strengthen the credibility and measurement validity of this research.

Research regarding productivity change when conducting hybrid working and ABW

While developing scenarios in this research, the possible productivity loss while conducting ABW and hybrid working is relatively dismissed. Although the productivity may not experience substantial loss in the pilot study case, because employees in Philips have already conducted hybrid working and ABW pre-COVID, this is only a justification for the pilot study case. Comprehensive research regarding the productivity change while conducting ABW and hybrid working needs to be done to further support the bandwidths construction. Because certain bandwidths shall be modified if the productivity in certain scenarios may experience unacceptable loss.

Research regarding possible revenue and expenditure

To make the findings of scenarios more valuable for corporation's strategy evaluation. Further research regarding the expenditure and revenue of scenarios can be done. This includes the possible save on the budget while reducing the office space, estimated expenditure of aggressively/ordinarily implementing smart building into the workplace, etc.

To conclude this sub-section, the recommendation for future research reveals that this study is just one piece of a big puzzle. Possible future research concerns with not just the industry of real estate management, but also big data science, economics, social science, etc. There is no end to learning.

7.4.2 Recommendation for practice

While limitations and recommendation of future research are mentioned previously. This research per se still has its value. Recommendation for practice is presented in this section.

Applying the proposed scenario planning methodology for CRE

In the expert panel, panellists gave positive feedback regarding the proposed methodology and case study findings. The proposed methodology can be applied to CRE to develop scenarios with office space demand estimates, whether the scope is properties of Philips or CRE of other organisations. Apart from applying this methodology to a single property, applying it to the CRE in a region is also feasible. The CRE department in organisations and real estate consultancy companies are targeted users of this methodology.

Due to confidentiality issues, the detailed information regarding ABW implementation plan, current survey, code used for data analysis, and space analysis sheet, etc, cannot be shared outside of Philips. Yet corresponding research can be done, scenarios can still be developed under the proposed methodology that is derived from literature review and market research.

Evaluating strategies based on scenarios

This practice can also be regarded as future research. Scenario planning can be served as a decision-making or evaluating base for CRE regarding their business strategies (Schoemaker,

1995). Therefore, with the scenarios with office space demand estimates developed, CRE strategies regarding lease/own, (re)locating, technology implementing, ABW implementing, and hybrid working implementing decisions, etc, can be evaluated.

As mentioned in further research regarding revenue and expenditure, further research based on proposed scenarios can be done to further elaborate the scenarios in order to provide a more holistic support on decision-making and evaluating.

To conclude this sub-section, the proposed scenario planning methodology is valuable for CRE to evaluate their decisions. It can be applied at a corporate or property level for CRE.

8 Reflection

This chapter presents the reflection regarding the reseach positioning, research relevance, research methods and approaches, and research process.

8.1 Research positioning

This master thesis is conducted under Delft University of Technology, master's programme of Architecture, Urbanism, and Building Sciences (AUBS), in the track o Management in the Built Environment (MBE). This research is conducted within the Real Estate Management (REM) domain of track MBE. REM focuses on managing and facilitating physical entities which house business activities of organisations. This thesis aims to propose a methodology of scenario planning that can develop scenarios with corresponding quantitative office space demand estimates so as to support the decision-making and evaluating process of corporate real estate (CRE). Such methodology is proposed and applied to a case in this thesis. CRE industry as part of REM can apply this methodology in a certain scope, the office space demand scenarios are valuable for organisations to manage their physical properties (real estate).

While this research is mainly in REM domain, it is also slightly concerned with Urban Development Management (UDM) domain. UDM focuses on managing the decisions of many stakeholders involved in the development of urban areas towards a high-quality outcome. With the scenarios of office real estate developed, scenario planning helps organisations to evaluate the future office real estate and workplace – which is part of urban areas.

8.2 Research relevance

Scientific relevance

During the literature review, it is found that no scientific paper introduced a holistic scenario planning methodology to develop scenarios with quantitative office space estimates at a corporate level. By identifying the lack of this knowledge as the research gap, the first objective related to scientific relevance in this research is to propose a scenario planning methodology that can result in scenarios with corresponding quantitative office space demand.

A methodology that combines scenario planning and office space demand forecast is proposed and further enhanced for the scope of post-pandemic through literature study. This methodology has its replicability – it can be applied to certain scopes in CRE industry. Through the application, quantitative office space demand scenarios can be developed.

Societal relevance

The future is not predictable, developing scenarios helps people to understand the future. This research addresses the urgent need of CRE to evaluate their future office real estate and workplace strategy due to the impact of the COVID-19 pandemic. This research identifies and analyses possible future trends that impact corporate office real estate. It provides CRE industry with a holistic analysis of the impacts of ABW, hybrid working, smart building, etc. As mentioned before, the findings of detailed scenarios are valuable information for CRE industry to evaluate their real estate strategies and manage their physical entities.

8.3 Research methods and approaches

Design process cycle

The iteration of the design process cycle in Figure 2.3.1 is only run once in this research. While the cycle is able to be run multiple times in the formal sciences research, the cycle can be ended if there is no 'clash' between the design and the problem after the design is realised/used. However, several problems remain unsolved in this research. For example, (1) the ExCo floor, reception floor, and restaurant were not considered in the scenario planning process. Although other supporting facilities were considered, leaving out several elements and assuming that they will remain the same makes the results less credible. (2) During share-ratio computation, the impacts of ABW and hybrid working are separately considered, there may be better approaches to deal with these impacts. Yet due to the time limitation of this research, these clashes remain unsolved. Future research should address the clashes so as to develop a better methodology and the research methods that are taken in the methodology.

Literature study

Because this research aims to propose a methodology that combines scenario planning and office space demand forecast and then apply this methodology to develop scenarios with corresponding quantitative office space demand. To familiarise the knowledge of relevant topics, identify the knowledge gaps, develop the methodology and propose research methods, the literature study is conducted.

Through this part of the research, a methodology of scenario planning that can incorporate office space demand methodology is proposed. The methodology is then calibrated by incorporating a suitable office space demand formula. Possible future trends that are needed for scenario planning are also identified. The proposed methodology is then elaborated to be able to develop post-pandemic office real estate scenarios with quantitative office space demand at a corporate level.

Pilot study – survey and its data analytics

The chosen case is Philips Center, the global headquarter of Philips. A large amount of data is acquired from Philips, including the dataset of FoW survey in Philips Center. The existing data analysis of FoW survey was conducted by R language, which is a programming language that the author has never learned or used. Through tens of thousands of lines of code from multiple files, the author managed to understand the code and modify it to fit the

requirements for this research. Although the learning process was hard, the author was quite satisfied with the outcome: the modified code ran well, the research got to proceed, and new knowledge is acquired.

Furthermore, applying programming language-based data analysis (coding) is rare in MBE master theses. Knowledge from another totally different subject needs to be acquired to conduct this research. The author wishes to explore more possibilities of incorporating this research approach into real estate industry.

Pilot study – interviews

Preparing interviews is relatively hard – due to confidentiality issue, the interviews had to be conducted with people within the organisation. Although there are experts regarding CRE, workplace solution, smart building, and data analytics in Philips, their expertise lies in different aspects. This means that the interview questions need to be modified and selected for almost every different interviewee so that the questions lie in their expertise. The takeaways from interviews would only be credible for the research in this way. Fortunately, findings from the interview are sufficient to produce output. However, limitations do exist in this research approach, they are mentioned in section 7.3 research limitations.

Expert panel

The exper panel helps to examine the replicability and validities in different aspects of this research. The evaluations and limitations are explained respectively in section 6.3 research evaluations and 7.3 research limiations.

8.4 Research process

While presenting the reflection of research process, this section is also regarded as a self-reflection. This section is therefore written in the first-person point of view.

With strong professional interests in corporate real estate and programming language-based data analysis, and personal curiosity about the future - the post-pandemic world, I initiated this research in September 2020. I believe it is substantially important to incorporate (big) data analysis into the real estate industry in the future, which is the reason why I intentionally tried to incorporate data analysis (coding) in my master thesis.

I tried hard to force the chunk of data analysis into my thesis, and perhaps this is part of the reasons that made me completely lost during the first few months of the research process. During the literature review process, I realised that I would need a considerably large amount of data to finish my research, and I did not know how I could acquire the data. This had made my research pause for quite a while.

However, life is not always as bad as it seems. I successfully attained an internship in Philips Real Estate when I was confused by my research. The job content of my internship is mainly

regarding analysing FoW surveys conducted in various properties in Philips. I much appreciate this opportunity as it helped with my personal growth and enlarged my knowledge base. The internship helped me find my focus of my research: addressing the space demand (as it is already complicated) and not incorporating business strategy as firstly planned. Through agreement, I could use Philips Center as the pilot case for my thesis. Thus, I acquired huge amount of data from Philips, without which my thesis may have gone into a totally different storyline. I realised one of the limitations of a master thesis: it is not possible to focus on a big picture with everything involved, the focus of the research needs to be sharpen.

The later research process went relatively smoothly. Although it was hard to balance a full-time internship and thesis writing, I have managed to produce output on both. The support I got from my mentors, Monique and Erik, was generous and extremely valuable. Their advice on my research is always insightful and farsighted – sometimes I had to work on the research for quite some time to fully understand the advice. When I looked back at the feedback and advice, I always held them in great esteem. The communication approach of addressing reading guides and questions to my writing components was productive. My main mentor Monique also offered a lot of encouragement and support during the time I was lost in my research, this made it possible for me to continue and finish my research.

Although I do see flaws and limitations in my research process, I have identified an important issue, spent a lot of effort to accomplish every piece of this research and produced detailed output. I am quite satisfied with what I have learnt during the process. Lastly, I hope this master thesis can provide one small piece to a big puzzle of corporate real estate.

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Appendix A - Interview brief and consent form

Interview Brief

Dear NAME,

With this letter, I would like to invite you to participate in my graduation study titled Post-pandemic Office Real Estate: Using scenario planning to give quantitative estimates on office space demand for corporate real estate. This study is carried out to fulfil my master's thesis in the Faculty of Architecture and the Built Environment, Delft University of Technology. This thesis aims to incorporate scenario planning methodology into office space demand estimation/forecast methodology and develop future scenarios with corresponding quantitative estimates regarding office space demand for corporate real estate (CRE). The final output of this research intends to provide probable scenarios of office of the future in order to help CRE evaluate their future office implementation plans.

This interview will last approximately 45 to 60 minutes. I would like to ask permission to record this interview for transcribing and analysing the information. The transcript would be coded anonymously, and the original recording will be deleted once the accuracy of the transcript has been confirmed. You can always say that you would rather not participate. You can also change your mind at a later date and withdraw your participation. During the interview, you are free to omit any question.

If you participate, I ask you to sign this consent form at the next page and return a PDF to me. I will also sign the letter and return the PDF to you. I do to ensure that I will treat your data and answers with confidentiality. As my thesis uses Royal Philips as the case study, all interviewees are within the organisation due to confidentiality issue and the purpose of interviews. In case there will be interviewees from outside Royal Philips, all confidential data from Royal Philips will not be shared unless agreed by Royal Philips. When I quote your words, I promise not to use your name. I will erase your name and contact details immediately upon completion of the investigation. An embargo agreement has been signed to ensure the confidential part of the thesis/report will never become public and will only be stored by the Board of Examiners for use by accreditation.

Should you have any questions about this study, please do not hesitate to contact me (email: z.cheng-1@student.tudelft.nl, ziyao.cheng@philips.com). If you would like to participate in this interview, could you please complete and sign the statement below and send me the PDF by e-mail?

Sincerely,

Ziyao Cheng

Interview Consent Form

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I declare that I have been clearly informed about this research. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
I understand that taking part in the study involves audio-recorded, with the sole purpose of transcribing the interview and analysing the information, after which, the recordings will be deleted.	☐	☐
Use of the information in the study		
I understand that information I provide will be used for only for academic purposes of this graduation project and corresponding presentation at TU Delft.	☐	☐
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	☐	☐
I agree that the transcription of my interview can be quoted in research outputs; my name will not be used when quoting.	☐	☐
I understand the embargo agreement will ensure that all confidential information will be put in a separate (confidential) part of the thesis/report that will never become public and will only be stored by the Board of Examiners for use by accreditation. The confidential part includes all data that is acquired from Royal Philips.	☐	☐

Signatures

NAME

_____	_____	_____
Name of participant [printed]	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Ziyao Cheng

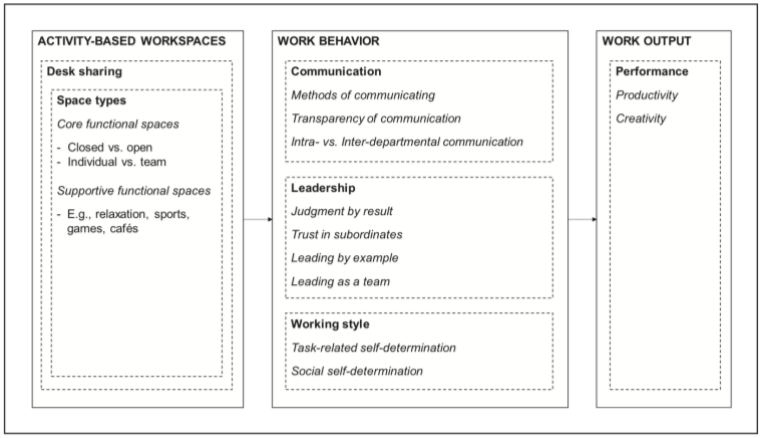
_____		_____
Researcher name [printed]	Signature	Date

Appendix B – Philips Future of Work Survey

Due to the Embargo agreement, appendix B will not become public.

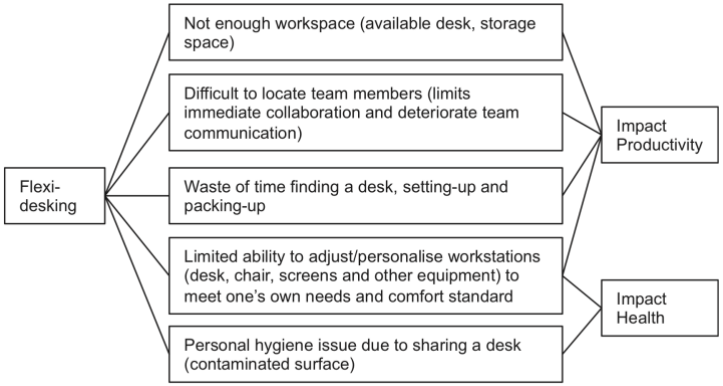
Appendix C – Literature study (section 4.2) summary

Activity-based working

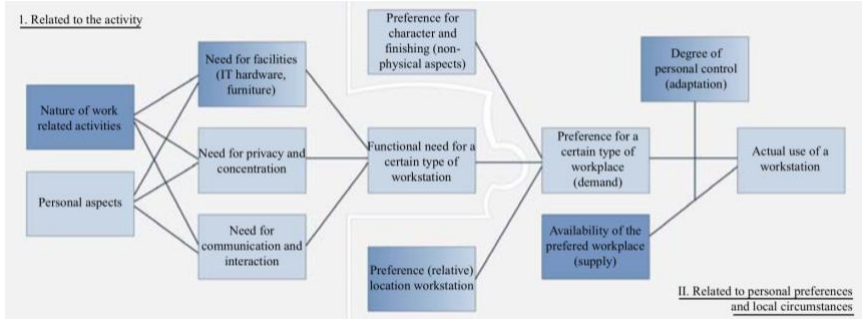
Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
Understanding the Mechanisms of Activity-based Workspaces: A Case Study (Eismann et al., 2021)	2021	N/A	Interviews	36 in-depth interviews including managers, change agents, and employees, all from the case - a German organisation which adopts ABW in its workspace	 Figure xx, Cause-effects-model of ABW (Eismann et al., 2021, p29) A cause-effects-model is developed. According to the model, ABW consists of three components: **(1) desk sharing, (2) core functional spaces, and (3) supportive functional spaces.** Desk sharing is a prerequisite of ABW. Core functional spaces are classified by two dimensions: closed-open workspace and individual-team workspace. The parameters of designing ABW are established, which is the left box of the model. Then a qualitative analysis of how the ABW parameters affect work behaviour and output is finished. Several propositions are made:

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					*"Proposition 1: In an ABW, desk-sharing and workspace **openness increase** interdepartmental communication, which in turn **increases productivity**.* *Proposition 2a: In an ABW, **closed** workspaces **provide** aural and visual privacy and **support** concentrated work, which **increases productivity**.* *Proposition 2b: In an ABW, desk-sharing and workspace **openness increase** distraction and loss of information, which **reduces productivity**.* *Proposition 3a: In an ABW, desk-sharing and workspace **openness increase** interdepartmental communication, which **increases creativity**.* *Proposition 3b: In an ABW, the increased availability of team workspaces and supportive functional workspaces **increases** informal interaction, distraction, and incubation, which **increase creativity**.* *Proposition 4a: In an ABW, **desk-sharing** in combination with workspace **openness** leads to greater spatial distribution of leaders and employees. In this environment, it is more effective **to evaluate performance in terms of results** rather than assessing work processes or depending on techniques such as observation.* *Proposition 4b: In an ABW, the availability of **supportive functional workspaces** increases the importance of **trust**, and **productivity and creativity are moderated by leadership styles that promote trust** between managers and subordinates.* *Proposition 4c: In an ABW, **desk-sharing** in combination with workspace **openness** reduces the salience of hierarchy. Managers' ability to **cope with this diminution of boundaries** between subordinates and managers and to **demonstrate how best to use** the ABW **moderates the effect of ABWs on productivity and creativity**.* *Proposition 4d: In an ABW, **desk-sharing** in combination with workspace **openness** prompts a shift toward **shared leadership**, which **increases inter- departmental cohesiveness** and **productivity**.* *Proposition 5a: Working in an **ABW** requires employees to coordinate and plan their activities, which **increases task-oriented self-determination**.* *Proposition 5b: Working in an **ABW** requires people to be more considerate in their dealings with colleagues, which **increases social self-determination**."*
Activity-based flexible office: Exploring the fit	2019	2019	A case study of an		Collaboration appears more in ABW compared to normal workplace, especially in more visible and accessible open areas.

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
between physical environment qualities and user needs impacting satisfaction, communication, collaboration and productivity (Zamani & Gum, 2019)			organisation piloting activity-based flexible offices (AFO), methods include systematic observations, space syntax and surveys.		The requirement of privacy promotes a bigger demand for enclosed ABW/alternative work settings. Several implications for ABW emerged from this study: • Providing single-occupant enclosed rooms would increase concentrated individual work and privacy, also allow more efficient use of multi-occupants enclosed rooms for their group interactions. • Establishing areas to support intra-team communication and collaboration. Defining certain areas for teams that require high intra-team collaboration would be better than merely establishing unassigned workstation. • Modulating the accessibility of workstations to provide more alternative ways of working. • Providing better control of noise and distractions.
The mindset of activity-based working (Skogland, 2017)	2017	2016	Semi-structured interviews	65 members from a Norwegian professional service network provider	Although spatial changes may well facilitate the intentions, yet such effects are not easy to predict before implementing. Managerial issues and concerns need to be addressed continuously during the whole implementing process of ABW.
Desk ownership in the workplace: The effect of non-territorial working on employee workplace satisfaction, perceived productivity and health (Kim et al., 2016)	2016	2012-2014	Survey	3974 respondents from 20 office buildings in capital cities in Australia, with average response rate of 45,2%	Reducing space per person under the purpose of implementing non-territorial work policy ***does not necessarily*** decrease occupant workplace satisfaction, perceived productivity and health.

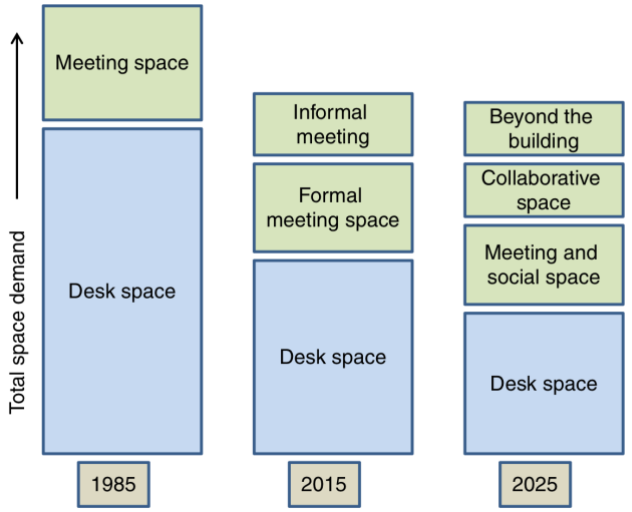
Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					 Figure xx, Possible negative impacts of flexi-desking arrangement on productivity and health (Kim et al., 2016, p211) Spatial layout design needs to be carefully treated to reflect the actual requirements of all kinds of organisational work processes, otherwise a potential negative effect of non-territorial workspace could be the decreasing effectiveness of collaboration.

Accommodating new ways of working: lessons from best practices and worst cases
(Brunia et al., 2016)
	2016	2007-2014	Survey. 7140 respondents from 52 different cases in 21 different organisations which all use flexible offices with ABW in the Netherlands.	2 successful cases and 2 less successful cases were used for this study. All with the share-ratio (seat/ employee) of 1/1,43.	• Open spaces should be used ***alternately*** with enclosed rooms that are designated for individual concentration.
					• Large open workspaces that accommodate more than 15 people should be avoided, or sufficient acoustic measures are needed to solve privacy or concentration issues.
					• Small meetings spaces should be ideally located near the working areas.
					• It is recommended to provide
					  ○ A variety of workspaces
					  ○ Separation between open communication and working areas
					  ○ Sufficient acoustic and visual privacy in open areas
					  ○ Open spaces should not be too large, better divided
					  ○ High mobility
					  ○ Daylights, sufficient IT support, clear behavioural manuals, etc.

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					• It is recommended to take care of ○ Commitment of the management ○ Reasonable information and communication about the concept ○ Managing expectations ○ Allowing employees to share their opinions ○ After care and quick responses
An end-user's perspective on activity-based office concepts(Appel-Meulenbroek et al., 2011)	2011	2009	Literature research and survey	182 end-users (survey respondents) from four different service organisations in the Netherlands	The office concept is not always used as what was intended which could result in sickness, dissatisfaction and decreasing productivity. Employees' personal preferences might have a bigger impact on the final satisfaction than the certain types of workplaces that are expected to be effective and satisfactory.  Figure xx, Preliminary model for choosing a workplace in an ABW office concept (Appel-Meulenbroek et al., 2011, p126) Different personal needs of employees make it hard to design and implement a general concept with all the different working styles and activities. Mixed results also came out in this research. However, there are still some implications can be found: ○ For semi-open workplace, employees prefer single lounge chair much better than duo-lounge chair which can be used by two people. ○ For open workplace, privacy and concentration issues are the main reasons of end-users trying to avoid it. Employees prefer *regular open workplace,* that is, open workplace with appropriate working surface, facilitated with IT equipment and suitable to be adjusted ergonomically.

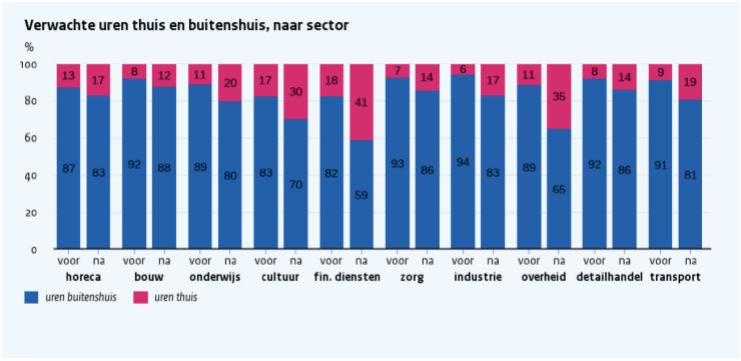
Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					○ For meeting facilities, user prefer more functional designed and furnished meeting facilities rather than beanbags. ○ For other facilities, pantries provide the best occasions for informal talk, therefore its ambiance is highly valued. Corporate real estate managers should seek a method that could identify the way of ABW will be actually used by the employees.
To use or not to use: Which type of property should you choose? Predicting the use of activity-based offices (Appel-Meulenbroek et al., 2015)	2015	Data collected in 2008-2009	A Bayesian belief network (BN) from a large database of survey	80907 observations of office use in three organisations from Belgium and the Netherlands	**A Bayesian BN is constructed, very interested but cannot be implemented in this thesis because it seems a bit out of my scope & capacity.**
Comparative study of the factors affecting the generativity of office spaces (Asefi et al., 2019)	2019	N/A (between 2012-2018)	Observation mapping and informal interviews	50 interviewees from two companies in Esfahan, Iran	Basic individual needs should not be sacrificed due to the need of promoting interaction, teamwork and collaboration. The change of new spatial layout and variables does not have a consistent relationship with the employees' behaviours because decision makers usually implement new changes regarding layout before changing organisational codes and cultures.
Are the myths of space utilization costing you more than you know?(Knapp et al., 2009)	2009	N/A (before 2009)	Data analysis of cases of companies	8 major companies and JLL's own office portfolio (research conducted by JLL)	Global recommendation of average office space per person is 20,9 sqm. While this number is higher in US, space required per person and per seat is lower in Europe and especially in Asia. European is shifting its metric focus from sqm per seat to occupancy rate. This states the necessity of considering both of them which are reflected accordingly by ABS and hybrid working.
Future office layouts for large organisations: workplace specialist and design firms' perspective(Nanayakkara et al., 2021)	2021	N/A (before 2020 (pre-COVID))	Semi-structured interview	8 workplace strategy consultants (interviewees) in Australia	Main considerations when organisations design new office layouts are flexibility, functionality, leading technology, acoustic settings, sense of community and generation gap between employees. Interviewees believed future offices will be technology driven, sustainable, community oriented, health and well-being focussed. More satellite offices which are smaller in the size such as co-working office spaces will appear. *Obviously, such research findings*

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					regarding the future of office did not change much between pre-COVID research and research conducted during COVID-19.
Productivity drivers of knowledge workers in the central London office environment (Chadburn et al., 2017)	2017	N/A (before 2015)	Survey	213 employees from 8 professional companies (consultancy, financial & media services) in central London, UK.	Comfort, convenience, IT connectivity, good design and a specific time scale of working are the strong drivers of personal productivity. For knowledge workers, an office that is flexible in terms of both enabling a working environment that is interaction-friendly and as well as quite individual workplace for concentration. There is usually more acceptance of open workspace after knowledge workers actually experiencing it. The acceptance is reflected by improved teamwork and communication in open workspace. Knowledge workers unanimously dislike the workplace setting of 'hot-desking', that is, a non-reservation-based desking sharing set-up that requires multiple employees using the same physical work surface during different time-periods. **It is therefore recommended that companies should be cautious when considering hot-desking as the results from the questionnaire suggests it is widely seen as having a negative impact on personal productivity.**
The changing nature of the workplace and the future of office space (Harris, 2015)	2015	N/A	Survey with the scope of London, UK and empirical data	N/A	Many organisations plan their space at around eight desks per ten workers, that is, as the share-ratio of 1,25. Average office space per person is around 11 sqm in 2013. In the future, the collaborative, meeting and social space will increase in order to enable the increasing needs of knowledge sharing and interaction. At the same time, conventional desk space will decrease with the promotion of WFH and hot-desk settings.

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					 Figure xx, The changing palette of work settings (Harris, 2015, p432)
Workplace trends in office space: Implications for future office demand (Miller, 2014)	2014	2012	Survey and empirical data	CoStar data which included a US national sample of millions of office leases. Surveys were sent to CoreNet Global members and smaller companies which were tenants of buildings managed by CBRE.	Office space per worker will decline over time, especially in the larger tenants that actually analyse how to use space more efficiently. Such decreases are mostly based on increasing utilisation rates. However, it is likely that such transition towards more efficient use of space will take many years.
Working in the world of the pandemic. (Tredinnick & Laybats, 2020)	2020	N/A	Focus group	Key members of the business information community	More flexible working arrangements will become the norm, rather than the exception More materials will be digitised, and we'll have less physical space.

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					Maintaining our working relationships virtually will be a more conscious effort. *"I read an article on the BBC news app at the weekend that speculated on how office life would change in the future even after a vaccine for COVID-19 had been produced. It covered everything from the change in the way office space is used and the materials used within that environment to the consideration of a home office set-up as most office work would be completed at home. Face to face work was reserved for special times when the richness of that communication form could not be replicated to the required level online."*
The Tetris office: Flexwork, real estate and city planning in Silicon Valley North, Canada (Pajević, 2021)	2021	mid-March to mid-April 2019	In-depth semi-structured interviews.	20 Canadian corporate consultants (7), real estate professionals (6) and city planners (7).	Even though there are more employees, less space is actually required per employee — the workplace actually shrinks even as the company grows. **Activity-based planning** allows for more flexible uses of space, so the office is not just shrinking, but is also expanding on a need-to basis — in other words, the office increasingly resembles a Tetris game, whereby pieces are assembled and disassembled continuously. According to real estate professionals, this flexibility has made it possible for companies to spend more on premium locations by needing less space per worker. What is more, this flexibility translates into flexible leases. The latter is especially important for start-ups and scale-ups that lack the capital of industry players like Deloitte and EY and cannot afford the rising rents. In sum, some companies turn to flex-work for branding and change, others for consolidation and cost-cutting, and others use it as a risk- aversion strategy. No matter the motive, certain kinds of spaces – cool, flexible, easily dismantled and just as easily assembled – are in demand. The real estate industry seems to be supportive of these changes. In sum, without critical interrogation, flex work will likely continue to contribute to the rising unaffordability of office space. Flex-work can be served as a talent attraction strategy, a cost-reduction strategy, and a planning conundrum. In sum, flex-work reduces the amount of space required per worker, thereby reducing the need for large offices.

Hybrid working

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
CfPB Persbericht Thuiswerk productiever dan kantoorwerk ((Hoekjen & Hoekstra, 2021)	2021	2020	Survey	40000 Dutch office workers, mostly from the national government	**82%** of the respondents in the wewerkenthuis survey indicate that they want to work from home (WFH) more often after corona; **87% of the respondents would not mind having to WFH for one or two days.** "We also asked about the number of hours people want to work from home," says Hoekstra. "The number of 16 hours is mentioned most often (more than 20%), followed by 24 hours (approximately 17%) and then 8 and 20 hours (approximately 10%)." **Regarding the effect of WFH/hybrid work mode on productivity:** The majority of respondents **(55%)** indicated that they are **more** productive at home than in the office. On average, homeworkers rate their own productivity with a **7,7**; office productivity was rated **6,7** in the pre-corona period. *Note: seems that the questions setting is similar to Philips'*
Thuiswerken vóór, tijdens en ná de coronacrisis(Jongen et al., 2021)	2021 Jan.	March-June 2020	Survey	4500 Dutch respondents from LISS panel (a representative sample of 4500 Dutch households, conducted by CentERdata)	It is expected that after the pandemic there will be **twice as much working** from home as before the corona crisis, but most of the working hours will still take place at the workplace. Before the corona outbreak, they worked at home on average for almost 4 hours a week. This is expected to be **8 hours a week after the corona crisis**.  Figure xx, Share of hours worked away from home and at home: before the corona crisis and expected after the corona crisis by sector (Jongen et al., 2021, p4)

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					The increase in working from home differs further **per sector**: in construction, hospitality and healthcare, the increase in working from home is expected to be limited due to the nature of the work. The expected increase is strongest in financial and business services and the government. **Regarding the effect of WFH/hybrid work mode on productivity:** Employers generally have few losses with an increase in home working, according to the empirical literature, working from home usually leads to higher productivity. Several causes of this higher productivity are mentioned in the literature. The factors mentioned most are a reduced travel time (Kazekami, 2020), an increased well-being (Bosua et al., 2012), fewer interruptions by colleagues (Bailey and Kurland, 2002).
The impact of COVID-19 pandemic on conventional work settings (Diab-Bahman & Al-Enzi, 2020)	2020 Aug.	2020	Survey	192 respondents from Kuwait in three sectors – banking and finance (61), education and training (68), and oil and gas (63).	Only **36% are expecting things to go back to normal** (pre-COVID-19 conditions) while even less supported the notion of giving employees an option to completely work from home. Also, **more than half of the respondents supported the idea of a hybrid model**. **More than 70%** of employees currently working from home reported that they can accomplish **at least 60–70%** of the expected workload. **More than half** of the respondents indicated that they could **achieve at least 80–90%** of the currently expected workload if a hybrid model of onsite and at-home work is established. **Regarding the effect of WFH/hybrid work mode on productivity:** The **majority** of people felt that they are more productive at home than at the workplace, as well as being able to concentrate more at home than in the office. There was almost an even split in when it came to getting their work done in less time at home, as **51%** reported in agreement and **49%** said they were unable to. *Note: no information regarding working hours composition of WFH and work in the office is given*
JLL Perspectives for Enterprises 2021 [Webinar] (JLL, 2021a)	2021 Jan.	2020	Survey to employees, also presentations of CRE directors in the webinar	2033 respondents, JLL Human Experience 2020 Survey	From employee's perspective, **50% of them want to work in hybrid mode after COVID, 26% choose exclusively outside of the office**, and the other 24% choose exclusively in the office. *Note: no information regarding working hours composition of WFH and work in the office is given*
Global office	2020	2020	N/A	Scope: Europe	The share of people working permanently from home in the U.S. and Europe increases

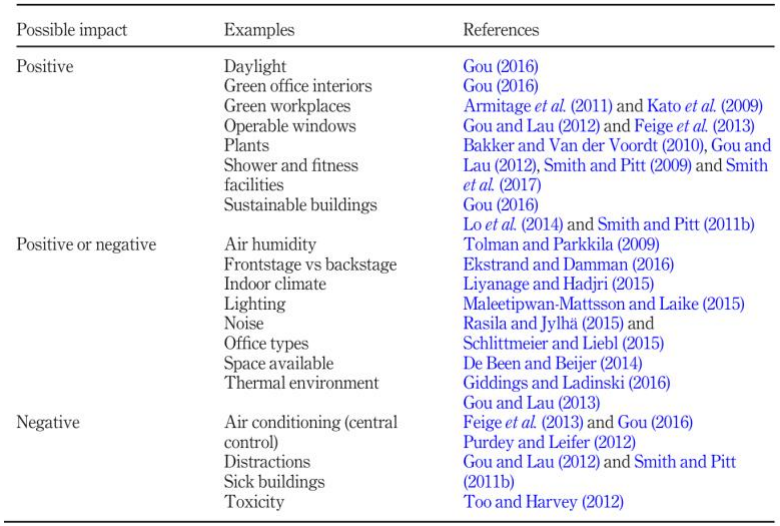
Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
impact study & recovery timing (Cushman & Wakefield, 2020a)	Sep.			& Global	from 5-6% pre-COVID-19 to **10-11% post-COVID-19** and that the share of agile workers who work in a hybrid mode increases from 32-36% **to just under 50%**.
Workplace Ecosystems of the Future (Cushman & Wakefield, 2020c)	2020 Oct.	2020	Focus group and interviews	32 investors (under $900B), occupiers ($574B in annual revenue) and place makers (business improvement district (BID) executive directors for submarkets in major U.S. downtowns containing over 350 msf of office space). All respondents are based in USA.	Corporation culture needs to be enhanced face-to-face. In-office employees are more likely to innovate and create. Due to such reasons, the future will be hybrid, and 100% remote working will be rare. The workplace of the future will be an ecosystem of multiple options for workers. **In post-pandemic world, remote working ranges from 1,5 days to 3 days per week in general.** Based on previous literature research and focus groups research developed by Cushman & Wakefield, **it is very unlikely that the average levels of WFH will go beyond 3 days per week in the long term.** In most scenarios considered by Cushman & Wakefield, the annual net absorption will decrease in recent years. Net absorption refers to the sum of area that became physically occupied minus the sum of area that became physically vacant during a specific period (JLL, 2017). This means that the office demand in the market will decrease in most scenarios, however, it is also indicated that this fluctuation is most likely to be within the market's experience. Cushman & Wakefield ran 100.000 simulations by using a Monte Carlo methodology to investigate the bandwidth of the number of days that office workers will work from home in the United States. **The results showed that the 'most-likely' situation of WFH is 2,25 days per week, the 'lowest' situation of WFH is 1,5 days per week, and the 'highest' is 2,9 days per week. These results are also supported by the focus groups.** Nevertheless, the result is explicitly of the United States. **When comparing the percentages of office workers *usually* (more than 2,5 days per week) WFH between the United Stated and the Netherlands in 2019, it can be found that this percentage of United States is 8,5% and it is 14,1% for the Netherlands** (Cushman & Wakefield, 2020b; eurostat, 2021b, 2021a)**.** The huge difference of the pre-COVID-19 data makes it very possible that the probable bandwidth of average WFH days post-COVID-19 in the Netherlands is different from that of the United States, and the 'highest' end is more likely to be even 'higher' in the Netherlands. **Regarding the effect of WFH/hybrid work mode on productivity:** WFH performance is better than 'expected'. Productivity has remained strong. (Note: It is

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					not explicitly mentioned if the productivity is higher than pre-pandemic time)
The influence of the COVID-19 pandemic on the digital transformation of work (Nagel, 2020)	2020 Aug	March-April 2020	Survey	Respondents resided in the United States, Italy, Spain, France, United Kingdom and Germany. The survey was conducted in English. The total sample size was 554. Respondents work in the crowdsourcing platform Amazon Mechanical Turk.	Employees believe that digital work will play a more important role as a secure source of income in the future than traditional jobs. There is a significant (1% level) increase in the importance of digital work overtime. People predict that digital jobs are more likely to be a secure source of income in the future than before and during the COVID-19 pandemic. Furthermore, people predict that traditional jobs will again increase in importance in the future, but they are considered significantly (1% level) less important as a secure source of income than before the pandemic. **People believe that digital transformation of work will spread faster, due to their experience with the COVID-19 pandemic.** The more people believe in an increased spread of digital transformation due to the COVID-19 pandemic, the more likely they are to imagine working exclusively digitally in the future. *Note: no information regarding working hours composition of WFH and work in the office is given*
Future of offices: in a post-pandemic world (ARUP, 2020)	2020 June	2020	N/A	Europe	With expenses in everything from energy to broadband usage to office rent reduced, many organisations will see remote working as an opportunity to cut some of their biggest financial commitments. **Thus, there is potential cost saving on promoting hybrid working.** *Note: no information regarding working hours composition of WFH and work in the office is given*
Workplace change within the COVID-19 context: a grounded theory approach. (de Lucas Ancillo et al., 2020)	2020 Oct.	March to July 2020	Analysing publications and surveys from March to July 2020	N/A	**The majority of people (56%)** felt that they are more productive at home than at the workplace, as well as being able to concentrate more at home than in the office. As a brief note, some reports indicate that prior to COVID-19, only 3% of the US office market was considered flexible space, while their growth was estimated at 25% annually during the last five-years. This means that flexible solutions were already present, and while there has been a 12% and 9% decrease in working time within headquarters and satellite offices, an increase of **20% to 27% in flexible office working** is projected.

Smart building solution / smart working

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
JLL Perspectives for Enterprises 2021 [Webinar] (JLL, 2021a)	2021 Jan.	N/A	Survey	N/A	**Health & wellness** of employees is a #1 priority for EMEA CRE directors in the medium to long term, while **technology** is #2. Top investment areas are well-being service, WFH solutions, collaboration tools in the office.
Focus 15: Analytics and Pandemics: What's Changed? [CoreNet Webinar] (Targell, 2020)	2020 Oct.	N/A	N/A	N/A	CRE's operational model will continue to undergo transformation, shifting from solely being agile to being able to facilitate the adaptive future-ready enterprise. Digital technologies will be implemented to create smarter, intuitive and personalised working environments in order to augment people's ability to work effectively.
Purpose of Place - History and Future of the Office (Cushman & Wakefield, 2020b)	2020 Oct.	N/A	N/A (Scope: Global)	N/A	5 dynamics for the future of office: Productivity & Output; Innovation & Creativity; Company Culture & Branding; Employee Satisfaction & Retention; Location & Building Strategy. While web cameras and teleconferencing can replace some of this interaction, it is argued that the spontaneity that comes from Walkable Urban Places is important. It is a force that tends to occur when people are physically interacting at the office and around the city as well.
Reimagine - The new future of work to shape a better world (JLL, 2021b)	2021 Jan.	N/A	N/A (Scope: Global)	N/A	Enterprises are more focused on their #1 investment: people. The new workplace purposes shall be Health & Well-being; Employee Engagement Experience; Culture & Pride in Belonging; Learn & Socialize Innovate; and Brand Experience.
COVID-19 Global Real Estate Implications	2020 Apr.	N/A	N/A (Scope: Global)	N/A	In the post-pandemic worlds, mega trends will continue to evolve - growth in corporate outsourcing; rising capital allocations to real estate; urbanisation; technology; sustainability.

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
Paper II (JLL, 2020b)					
EMEA Office Markets Update – The Current State of Play | Opportunities and Risks on the Road Ahead [Webinar] (Colliers, 2020)	2020 Oct.	N/A	N/A (Scope: EMEA)	N/A	It is suggested that there will be higher demand of flexibility across portfolios in the future. *Increased demand for flexibility in traditional office leases, increased demand for flexible workspace and coworking solutions,* and *increased demand for space in newer, sustainable, high quality buildings with compelling tenant amenit*ies are the three most acknowledged primary impacts of the COVID-19 pandemic to future demand for office space. The biggest changes should be made to traditional offices to enable the work in future are recognized as HR policies that support flexible and dynamic working, and conference and meeting room technology to accommodate in person and remote participants.
Healthy workplaces: what we know and what else we need to know (Jensen & van der Voordt, 2019)	2019	N/A	Literature research with the scope of all papers in 4 CREM and FM journals from 2008-2017	N/A	Apart from particular influencing factors that influence Healthy Workplaces (HWs), such as plants, light setting and indoor climate, various papers also show that spatial layout, especially the level of openness and environment for communication, concentration and privacy, and interior design have great impact on HWs.

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
					 Figure xx, Possible impacts of different physical aspects on HWs (Jensen & van der Voordt, 2019, p108)
Health and Wellbeing in Modern Office Layouts: The Case of Agile Workspaces in Green Buildings (Laughton & Thatcher, 2019)	2019	N/A	Survey	1853 respondents from a prominent South African medical aid administration company with the response rate of 29,5%	***ABW*** as a less territorial space that supports the requirements of tasks, and ***private enclosed workspace*** give the end-users **higher** comfort regarding physical and psychological health **than** ***open-plan office space*** that represents co-located and segmented individual workstations. This is because ABW (agile workspaces) allow employees to gain the control over the environment they want as the workspace is unassigned but reservable.
Smart work: Supporting employees' flexibility	2016	2012-2012	Survey, database and semi-structured interviews	Survey was run in 100 Italian companies, the database	The results showed that there is complementarity between the elements that characterise the Smart working (SW) model, and at least two elements are developed in each SW model. If these three factors are all developed, enterprises will achieve higher productivity. These three elements are ICT, HR and workplace layout.

Possible impact	Examples	References
Positive	Daylight	Gou (2016)
	Green office interiors	Gou (2016)
	Green workplaces	Armitage *et al.* (2011) and Kato *et al.* (2009)
	Operable windows	Gou and Lau (2012) and Feige *et al.* (2013)
	Plants	Bakker and Van der Voordt (2010), Gou and Lau (2012), Smith and Pitt (2009) and Smith *et al.* (2017)
	Shower and fitness facilities	Gou (2016)
	Sustainable buildings	Lo *et al.* (2014) and Smith and Pitt (2011b)
Positive or negative	Air humidity	Tolman and Parkkila (2009)
	Frontstage vs backstage	Ekstrand and Damman (2016)
	Indoor climate	Liyanage and Hadjri (2015)
	Lighting	Maleetipwan-Mattsson and Laike (2015)
	Noise	Rasila and Jylhä (2015) and Schlittmeier and Liebl (2015)
	Office types	De Been and Beijer (2014)
	Space available	Giddings and Ladinski (2016)
	Thermal environment	Gou and Lau (2013)
Negative	Air conditioning (central control)	Feige *et al.* (2013) and Gou (2016)
	Distractions	Purdey and Leifer (2012)
	Sick buildings	Gou and Lau (2012) and Smith and Pitt (2011b)
	Toxicity	Too and Harvey (2012)

Source	Published Time	Moment of research	Methodology (survey / # questions or focus group)	# Respondents	Major findings
through ICT, HR practices and office layout (Raguseo et al., 2016)				contains the financial data of these companies, 49 semi-structured interviews were conducted with HR and other knowledgeable informants involved in Smart working implementation process	A complete SW implementation should include all of these three elements. In other words, SW corresponds to a work practice, which is characterized by flexibility in space and time, supported by technical tools, and provides the best working conditions for all employees of the organization to complete tasks. To achieve a successful SW implementation, the common effort of ICT, HR and CRE departments is needed.

Appendix D – Code of survey data analytics

Due to the Embargo agreement, appendix D will not become public.