The utilization of office spaces and its impact on energy use

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Abstract
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The foundation STUNS is investigating a possible move of the Origo office with tenants to a new office space. The Origo office today has a low utilization rate which makes it interesting to investigate the possibility of having an office space based on the ratio of occupancy. The purpose of this study is to calculate a ratio of occupancy with the corresponding risk of overcrowding and estimate the energy reduction. When adapting the new office space to the optimal ratio of occupancy, three office design proposals will be created. With the chosen optimal ratio of occupancy at 68 percent, the risk of overcrowding spanned between 0.3 to 0.6 percent. All proposals based on the optimal ratio of occupancy lead to electricity and cost reductions. An open office design leads to an electricity reduction of 686 kWh and a cost reduction of 168 kSEK per month. An activity based workplace leads to an electricity reduction of 540 kWh and a cost reduction of 132 kSEK per month. An individual office design leads to an electricity reduction of 452 kWh and a cost reduction of 111 kSEK per month.

A sensitivity analysis is made by altering input parameters. The analyzed parameters are the unique attending employees, the transition probabilities and the choice of risk of overcrowding.

For optimal utilization an open office space is the best alternative because it requires least square meters based on the same ratio of occupancy and workspaces. But when considering more aspects about work habits, employees’ opinions and behaviour the optimal office design may need a different structure.
# Table of contents

| Terminology | 3 |
| 1. Introduction | 4 |
| 1.1 Purpose | 4 |
| 1.2 Limitations | 5 |
| 1.3 Structure of the report | 5 |
| 2. Background | 6 |
| 2.1 Energy efficiency and sustainable development | 6 |
| 2.2 The Origo office | 7 |
| 2.3 Office designs | 8 |
| 2.3.1 Individual office | 9 |
| 2.3.2 Open office design | 9 |
| 2.3.3 Activity-based workplace | 9 |
| 3. Methodology | 11 |
| 3.1 Methodology overview | 12 |
| 3.2 Arrival and departure statistics | 12 |
| 3.3 Employee questionnaire | 13 |
| 3.4 Meeting room statistics | 13 |
| 3.5 Stochastic model | 14 |
| 3.5.1 Definitions | 14 |
| 3.5.2 Equations | 14 |
| 3.6 Model simulation | 15 |
| 3.7 Calculation of electricity savings and cost reduction | 16 |
| 4. Results | 17 |
| 4.1 Employees’ estimation on working habits and thoughts on the work environment | 17 |
| 4.2 Meeting room statistics | 18 |
| 4.3 Unique arriving employees | 20 |
| 4.4 Employee attendance | 21 |
| 4.5 Ratio of occupancy and risk of overcrowding | 22 |
| 4.6 Energy and cost reductions | 23 |
| 5. Office design proposals | 24 |
| 5.1 Proposal 1: Open office space | 24 |
| 5.2 Proposal 2: Activity based workplace | 25 |
| 5.3 Proposal 3: Individual office design | 26 |
| 5.4 Electricity reductions and rent and ventilation cost reduction | 27 |
Terminology

Origo office = the collective name of the entire office STUNS is renting from Vasakronan and subletting to 10 different companies.

Utilization rate = the ratio between utilization and capacity

Ratio of occupancy = the ratio between number of workspaces and number of employees

Overcrowding = more people at the office than the office space is adapted for
1. Introduction

There is a public interest for new solutions toward a more environment-oriented society today. Regulations and pressure from state and public authorities are increasing since there is an extensive need for solutions with a low environmental impact. The interested of companies’ for environmental issues has increased since different studies have shown that good values regarding environment issues and human rights makes a company more attractive, both for customers and employees and should therefore be a high priority strategy for every business (Miljö och Utveckling, 2015). Reducing the energy use leads to a reduction of the environmental impact, which favours cost reductions, and a larger overall profit. At the same time it gives companies positive promotion and favours sustainable development (Energimyndigheten, 2015).

It is common for construction and real estate companies in Sweden to search for technological solutions when energy efficiency improvements are being made but similar results could be reached by a change in behaviour. The EU directive on energy efficiency from the European Commission points out that energy efficiency improvements can be achieved by technological, behavioural and/or economic changes for the office structure that requires less electricity, square meters or costs (European Commission 2015).

The Swedish foundation STUNS works to improve the collaboration between the universities in Uppsala, the public organisations and the business community to support the development of companies in new fields. STUNS is currently renting an office space from the real estate company Vasakronan and subletting it to ten other companies. Origo office is the collective name of the entire office STUNS is renting from Vasakronan (Stuns, 2015). STUNS is planning on changing office location and looking for ways to reduce their energy use. They are especially interested in studying the behaviour of the employees and how that can contribute to a proposal of a more energy efficient design for the office space.

By examining how much of the current office space is utilized a conclusion about the optimal ratio of occupancy can be drawn. The optimal ratio of occupancy means the ratio between number of workspaces and number of employees. If the optimal ratio of occupancy, and the employees’ requests, opinions and working pattern are known, a proposal of a more energy efficient office design and an optimal working environment can be produced for them.

1.1 Purpose

The purpose of this project is to examine which electricity and cost reductions can be achieved by adjusting the layout and size of the Origo office with regards to the ratio of occupancy, the number of available workspaces. Three different proposals are developed for the design of the office based on the ratio of occupancy. One proposal
only takes energy and cost reductions into consideration when developed meanwhile the other two proposal includes factors such as the employees’ requests and opinions as well as energy and cost reductions.

The following questions will be addressed in this study:

- What number of workspaces will result in the highest utilization rate (the ratio between utilization and capacity) and at the same time have an acceptable risk of overcrowding?
- Which types of office designs are possible to achieve a decrease in square meters of the office space?
- What electricity and cost reduction can be achieved by adapting the office to the optimal ratio of occupancy?

1.2 Limitations

The compilation of data is based on attendance statistics from March 2015. The entire month will be examined to compile an average day that will be used in calculations. The compilation of the meeting room statistics is based on data from February and March 2015. The compiled months will produce an average distribution for how the meeting rooms are utilized. This gives information and statistics for this study, even if it can be a significant difference between years and months.

The final electricity, rent and ventilation reduction will be calculated on a factor based on the optimal ratio of occupancy, with a linear ratio between the office area and energy use and cost. The ratio may not be linear due to high-consuming machines may be needed in the same proportion independent of the office space. Depending on the quality of the rental property and whether heating cost is included the rent will differ between different offices.

1.3 Structure of the report

Section 2, Background, explains why this project is important from an energy efficiency and sustainable development perspective. In the background we also explain our object that we are investigating, Origo office, and information about different office designs that we use in our proposals later in the report. Section 3, Methodology, explains our different approaches to collect information that we later use in our results. When presenting our results we use tables and graphs for a clear overview. In Section 5, three office design proposals are presented and in Section 6, Discussion, our results are discussed with a wide perspective where aspects such as society, economic and environmental sustainability are studied and analysed.
2. Background

This section starts with a general background to energy efficiency as a way to achieve sustainable development. After that the current situation at the Origo office is explained in terms of office design, layout, facility, square meters and number of employees. Different office designs will also be presented.

2.1 Energy efficiency and sustainable development

The Brundtland report that was published in 1987 presented a new concept - sustainable development. Since then there have been a lot of different approaches and definitions for sustainable development but they all include factors such as economic, social and environmental development. This study focuses on the environmental aspect of sustainable development by examine one possible improvement in energy efficiency. In this project the Brundtland Commission's definition of sustainable development is used. The Brundtland Commission's report defined sustainable development as:

"Development which meets the needs of current generations without compromising the ability of future generations to meet their own needs" (Burton 1987).

Since 1987 sustainable development has become increasingly integrated in all aspects of society. It has a more central role in politics, business, and the public sector and in citizens daily lives. In 2012 the European Union (EU) formulated a directive that required all countries connected to the EU to improve the energy efficiency at all stages of the energy chain, from production to final consumption. Sweden was one of several countries that defined an indicative energy efficiency target to help achieve the directions. By 2020 energy use in Sweden should be 20 percent more efficient compared to 2008 and a 20 percent reduction in energy intensity between 2008 and 2020 should be achieved (European Commission 2015).

As mentioned sustainable development permeates all aspects of society, businesses and companies are no exception. All companies worldwide are dependent of energy. A reduced use would lead to an increased operating safety and a reduced vulnerability. The energy supply is unpredictable due to disturbances like natural disasters, floods and conflicts between energy producing countries. Accurate management of the factors lead to increased competitiveness and profitability in comparison to other companies. By reducing the energy use the company also contribute to a reduction of carbon dioxide emissions. Major improvements that can be done is for example specific production development, hydraulics- and ventilation regulation during nights and weekends, improved seal in the office walls and doors and reduced leakage in the air pressure system. It’s difficult to locate minor improvement factors like losses in electronics and water consumption (Energimyndigheten 2009).
Energy efficiency for a company means optimizing the use of every bought kWh. There are many reasons to optimize the energy use of the individual company aside from the sustainable development perspective. Reducing the energy cost leads to a larger overall profit, satisfied requirements from laws and authorities and positive publicity for the company. A company faces a lot of obstacles on their pursuit of energy efficiency improvement. They have to consider both economical and social aspects. It is vital to compare investment in relation to amount of work it takes to implement and cost as well as energy use reduced over time (Energimyndigheten 2009).

As mentioned before it is common for companies to search for technological solutions when it comes to energy efficiency improvements but an equal improvement could be reached by a change in behaviour. The EU directive defines energy efficiency improvements as an increase in energy efficiency as a result of technological, behavioural and/or economic changes. The directive also emphasizes the importance of energy efficiency improvements at all stages of the energy chain (Energimyndigheten 2009). Decreasing the energy use of the Origo’s office is an action in line with the EU directive and is an improvement at the final stage by reducing their energy use.

2.2 The Origo office

STUNS is planning on moving the entire Origo office to a new office space and therefore they are seeking new solutions for how they can plan a new and more efficient office. Origo’s office space today has an interior consisting of individual offices. However, according to studies individual offices lead to a low utilization rate. Optimizing the ratio of occupancy makes it possible to design a more area efficient office and therefore the energy use based on square meters is reduced. To be able to optimize the office space it is probably necessary to replace the separate personal offices with shared offices or an open plan for their workspaces. It will require less space, lighting and ventilation and has other non-energy related benefits as well (Ability Partner 2013).

There are many ways for companies to work in agreement with the definition of sustainable development. The first step to become more sustainable and energy efficient is to regularly discuss and set up goals for the energy use. A company can for example choose to only use electricity that is produced from renewable resources to have more sustainable energy use (Energimyndigheten, 2009, s.34). STUNS and the Origo office are taking a different way towards becoming more sustainable by analysing the connection between the ratio of occupancy and energy reductions.

STUNS has a central role organizing and coordinating important contact at the interfaces between universities, business and public sector. STUNS is currently renting their office from Vasakronan which is one Sweden’s leading real estate companies (Vasakronan 2015). STUNS are subletting the office space to ten different companies: CONNECT Uppsala, DUO Revision, TRIO Redovisning, Forskarpatent AB, Almi
Invest AB, SLU Holding AB, Uppsala BIO, Uppsala Innovation Centre AB, UUAB Holding, UU Innovation. STUNS and STUNS Energy also have their office at this location. (Uppsala Science Park 2015)

The Origo office is 1700 square meters and has 62 individual offices (Vasakronan, 2010). There are also 10 meeting rooms of different sizes. The office space has a kitchen and dining room where the employees can get a cup of coffee, prepare food and microwave their lunch. Other public areas are toilets, shower room, reception and storage room (Börjesson 2015). The current area of the Origo office is 27 m² per employee including the individual office and all common areas (STUNS 2015).

In 2014 Origo’s electricity use reached 14.2 MWh. That means that one square meter of the office has an electricity consumption of 8.35 kWh per year (STUNS, årsammanställning av elanvändning). One kWh of electricity approximately cost 1 SEK which means that the total cost for electricity was approximately 14 kSEK per year. The Origo office has a rent of 870 kSEK per quarter excluding valued-added tax but including costs for ventilation, heating and cooling which results in a rent per square meter of 512 SEK per quarter. Heating, ventilation and cooling is approximately between 7 and 8 percent of the total rent costs (STUNS, hyresavi kvartal 2 April-Juni 2015).

2.3 Office designs

Today the layout and design of an office space varies a lot. There is for example individual, combination, set workplace/desk, flex, activity based and open office design. It is the type of work and the needs from the employees that should decide how the office should be designed. It is also important in all types of office designs that the employees feel like they have a say and can influence their work situation and work environment (Arbetsmiljöverket, 2009).

In older properties it is estimated that a space of 25-35 square meters per workspace (per employee) is required regardless of design. In newer, modern properties that estimation is lower, 17-22 m² per workspace. The reason for the decrease in area is that modern buildings often are designed after a more open office design and more efficient ventilation and cooling systems (Vasakronan, 2015). The total area includes space used for meeting rooms, storage, lunchroom, toilets, corridors and other necessary facilities (Arbetsmiljöverket, 2006).

This project will present three types of office designs more thoroughly. The designs presented are; individual office design, activity based workplace and open office design. These different types represent a closed work environment, an open work environment and a combination of both.
The standard ratio of occupancy companies usually choose when designing a new office with no personal workspaces is between 70 to 80 percent. Of course, this number can vary depending on how the company works and their utilization, but this is standard numbers commonly used (Boberg, 2015).

### 2.3.1 Individual office

An individual office design is defined as having a maximum of three employees. The offices are often placed on a line together wall to wall and each office contains one window for natural light. A corridor works as a link between all the individual offices and rooms with less need of windows, for example storage- and meeting rooms, are placed in the centre of the office space (Kontor och kontorslandskap, 2013).

The advantages of having an individual office are privacy and access to a quiet and undisturbed space in the office. Delicate work and conversations can easily be performed without the risk of disturbance or colleagues and customers overhearing confidential information. Another advantage is the control of the physical work environment like temperature and lighting. The disadvantages of individual offices are the limited overview of the office, which leads to less exchange of information. The social community of the company can seem as inferior compared to other office designs that encourage spontaneous conversations and buzz where experiences and knowledge is shared between colleagues. Another disadvantage is the cost of the office design. Individual offices often require more area per employee than other office designs (Kontor och kontorslandskap, 2013).

### 2.3.2 Open office design

The concept behind an open office space is that it simplifies communication and benefits a more natural flow of ideas among employees. Scientific research shows that usually there are beneficial aspects such as more cohesive teams and better cooperation between co-workers. It can also give leaders a better overview of the company and current projects. There are still some less favourable aspects such as a louder surrounding. Scientific research shows that sometimes an open office space has a negative impact on the company's productivity due to the fact that it is harder to stay focused. Employers not used to the open plan might experience more distraction. The office structure requires meeting rooms, quiet areas and telephone rooms so that the employees still can be able to accomplish the same work tasks despite more shared, less private surroundings (Inc, 2014).

### 2.3.3 Activity-based workplace

An activity-based office design does not have individual offices or desks for the employees. Instead the design of the office is based on different working environments that are best suited for various work tasks. Different working environments could for
example be quiet areas, phone booths, meeting rooms and desk areas. The employees often have a storage locker for their office supplies such as computer, documents and personal items. After they have gathered their supplies they are free to choose in which environment they prefer to work in (Vasakronan, 2014).

There are advantages and disadvantages with having an activity based design for an office. It often needs less office space in comparison to an individual office design. As a consequence of a smaller office an activity-based workplace saves money and reduces its impact on the environment. Other advantages of an activity-based workplace is that it encourages teamwork and creativity since it is easier for employees to interact with each other. One of the disadvantages of an activity-based workplace is that the employees can experience a lack of ownership over their job, which can affect accountability over the work done (Clarius, 2015).

When deciding to change from individual office design or other office designs to an activity based workplace it is of importance for the company to do a thoroughly investigation regarding the company’s and the employees’ needs. A change in working environment is more than just changing the design and furniture; it is also a change in behaviour. Therefore it is of importance to have an open dialogue between management and employees about the changes. The transition to activity based workplace takes time and employees involved in the process can more easily adapt to changes in working habits (Det nya arbetslivet, 2014).

When changing to an activity-based office design one of the most important things is to have a good IT system for the employees to use. Since the employees in an activity-based office design do not have access to a personal workspace, it makes the work much easier with portable documents. A well functioning IT system with all information and work stored at one place that every employee understands and uses frequently is necessary (Boberg, 2015).
3. Methodology

This investigation is based on data obtained from an employee questionnaire, several interviews with David Börjesson (project leader at STUNS Energy), an interview with STUNS CEO Christina Frimodig, an interview with Karin Boberg from Vasakronan, attendance statistics and meeting room statistics. The data is used to calibrate a Markov chain model with two different states. The Markov chain is used to be able to estimate the risk of overcrowding the office depending on the number of workspaces. The transition probabilities are calculated in Excel and in the next phase the transition probabilities are implemented in a previously constructed in a Matlab model.

A table for the ratio of occupancy will be produced based on the number of workspaces divided on the total number of employees. Each ratio of occupancy will have a corresponding risk of overcrowding, which means more people at the office than the office space is adapted for. A lower limit of risk of overcrowding will mean lower utilization rate and energy efficiency. The chosen optimal ratio of occupancy will take factors such as acceptable risk of overcrowding and energy and costs reductions into consideration when calculated. In the next step the optimal ratio of occupancy is calculated three different proposals for the office design will be made. All designs would utilize the office space in a more energy efficient way compared with how it is designed now.
3.1 Methodology overview

The flowchart illustrates the execution order of the project where the process starts in the upper left corner and ends in the lower right corner. Firstly the blue marked boxes that are located on the left side of the figure are collected. The access badges are used to extract information about the arrival and departure frequency at different times during the workdays and unique attendance. The probabilities calculated are used in a Markov chain of two states and are implemented and in a Matlab model. The Matlab simulation results in two key components, the risk of overcrowding and the optimal ratio of occupancy. With a chosen optimal ratio of occupancy, information about employees’ estimation on working habits and needs collected from the employee questionnaire and meeting room statistic the proposals for different office designs are developed. The decided proposals in combination with electricity and rent cost are used in the final calculations regarding the electricity consumption and cost reductions.

3.2 Arrival and departure statistics

Every time an employee uses his or her access badge to either leave or arrive to the office, a computer system registers the activity. For the month of March 2015, there are about five hundred pages of data containing all activities for when the badges were used. To be able to compile the data for every weekday, the day is divided into intervals of fifteen minutes. During every interval, the number of arrivals and departures are counted and the results are inserted in a list that shows how many employees are at the
office during every time interval. With that information it’s possible to produce a mean value for how a standard day looks regarding arrivals and departures to the office and number of present employees at the moment.

When the data was compiled the number of employees was negative at the end of the day. The explanation is that when employees leave for lunch, they often arrive in groups and only use one access badge. To reach a non-negative number of employees attending work each day the arrival frequency were corrected by adding assumed arrivals early in the morning and after lunch to make the model more realistic. However, the correction does not affect the maximum number of employees at the office at the same time, but it gives a higher probability of coming back to office after lunch.

From the arrival and departure statistic log, it is also possible to count the number of unique employees that arrive at the office every day. After counting the number of employees that attend the office every day a mean value is calculated and with complement to the arrival and departure statistics there is now also data of how many different employees attend the office in a standard day.

### 3.3 Employee questionnaire

A questionnaire was sent to the employees working at the Origo office. The questions are presented in Appendix B. The response rate was 55 percent when the data was compiled. The questionnaire is used to verify the obtained data from the attendance statistics. The questionnaire also includes information of what parameters in the office the employee’s value and if there is anything they are missing in their current office space. This information will contribute to the development of the different proposals for a new office design.

The employee questionnaire gave an average of 54 unique attending employees per day. To randomize a number of attending employees a customized normal distribution was created. The normal distribution contained a mean value of 54 and standard deviation was chosen to make sure that that the maximum number of employees does not exceed 62 employees. The problem with this approach is that the variance may not reach values that could have been included if the standard deviation was based on statistics.

### 3.4 Meeting room statistics

The Origo office has a booking system online for meeting rooms that is used by all employees. The meeting room booking system statistics is compiled for February and March 2015 and gives an indication of how the meeting rooms are utilized and the distribution between the different rooms based on location and size of meeting room.

It should be noted that the attendance and meeting room data may differ depending on day of the week, season, vacations and time-consuming project out of office. Since the
purpose with this project is to find the optimal ratio of occupancy and adapt the office to that ratio it does not matter if there are less employees at the office during for example the summer season due to vacations. The office still has to be able to facilitate all the employees during a busy period.

3.5 Stochastic model

The stochastic process contains two states, which in our model correspond to being at the office or out of office. Each time step contains unique probabilities to stay or leave the present state. Simulation over the time series produces a daily profile for the movement of one employee (Sandels et al., 2015).

3.5.1 Definitions

The Markov-chain model is based on the following definitions:

$N = \text{total number of employees at the office}$

$E_{\text{mean}} = \text{the mean value of how many employees come to the office on a standardized day (with no more absent employees than usual due to work out of office, vacation or illness)}$

$E^t = \text{Number of employees in attendance at the office a specific time interval}$

$D^t = \text{number of employees leaving the office a specific time}$

$A^t = \text{number of employees arriving to the office a specific time}$

$p_1 = \text{probability that an employee is at the office}$

$p_2 = \text{probability that an employee is out of the office}$

$p_{ij}^t = \text{probability that an employee in state i and moves to state j}$

3.5.2 Equations

By compiling arrival and departure statistic results, it is possible to calculate the probability of being in (state 1) or out (state 2) of the office and the probability transitions $p_{11}^t, p_{12}^t, p_{21}^t, p_{22}^t$ is calculated in every time interval using one day. (Formel och tabellsamling för grundkurs sannolikhet och statistik, 2013)

The probability of being in state 1 at a specific time

$p_{11}^t = E^t / E_{\text{mean}}$ (1)

The probability of leaving state 1 and go to state 2 at a specific time

$p_{12}^t = A^t / E^t$ (2)

The probability of leaving state 2 and go to state 1 at a specific time

$p_{21}^t = D^t / (E_{\text{mean}} - E^t)$ (3)

The probability of being in state 1 and stay in state 1 at a specific time
The probability of being in state 2 and stay in state 2 at a specific time
\[ p'_{22} = 1 - p'_{21} \] (5)

The probabilities of being in state 1 or state 2 sum up to 1, which correspond to 100 percent
\[ p'_1 + p'_2 = 1 \] (6)

To give some more practical insight into how the calculations are made an example of the calculations made in one time interval are presented below. \( E^t \), the number of employees in attendance at the office between 09.00am and 09.15am, \( E_{\text{mean}} \), the mean value of how many employees that comes to the office a standardized day \( A^t \), the arrival frequency and \( D^t \), the departure frequency, are parameters extracted from the access badge statistics.

\[ P'_{1} = E^t / E_{\text{mean}} = 23.7/47.75 = 0.496 \]
\[ P'_{2} = 1 - P'_{1} = 1 - 0.496 = 0.504 \]
\[ P'_{12} = A^t / E^t = 0.7/23.7 = 0.030 \]
\[ P'_{11} = 1 - P'_{12} = 1 - 0.030 = 0.970 \]
\[ P'_{21} = D^t / (E_{\text{mean}} - E^t) = 5.5/24.05 = 0.229 \]
\[ P'_{22} = 1 - P'_{21} = 1 - 0.229 = 0.771 \]

3.6 Model simulation

When all probabilities are calculated, they are implemented in a previously constructed Matlab script for repeated simulations (Sandels et al., 2015). In these simulations, occupancy profiles are generated by randomly sampling which transitions (arrivals and
departures) are taking place, based on the calculated probabilities. After running several simulations, a sequence of daily profiles has been generated, showing the probability of a random employee being present at the office in every time interval.

The previously constructed model requires as input parameters, all transitions probabilities for all time intervals and the number of present employees on the actual day. The output is a three dimensional matrix containing the occupancy for each individual employee for the specific day.

The probability transitions \( p'_{11}, p'_{12}, p'_{21}, p'_{22} \) forms a 2x2-matrix for each time interval. Each interval is equivalent to fifteen minutes and the actual day is divided into 65 time intervals between 06:00 to 22:00 per simulation. The number of present employees on each simulated day is generated through a normal distribution compiled from data of present employees for each weekday in March 2015. When summarizing the model simulations, present employees are plotted against the time span. By dividing the number of intervals exceeding a certain value with the total number of intervals, the comparison presents a risk of overcrowding the office with too many employees present at the same time. Deciding a suitable risk of overcrowding is further used to determine an optimal ratio of occupancy for the office.

### 3.7 Calculation of electricity savings and cost reduction

When developing the different proposals, the optimal ratio of occupancy, the employees’ wishes, opinions and theories about different office environment are taken into consideration. In the calculations regarding electricity and cost reductions the study uses a linear correlation between the size of the office and the energy use and the rent. To be able to draw a conclusion on how much energy and cost reduction can be achieved, information regarding energy use and the size of the rent is needed. Note that the new values are calculated with the current electricity and rent cost per square meter.

The new electricity consumption is calculated as:

\[
E_{\text{new}} = \frac{E_{\text{present}}}{A_{\text{present}}} \times A_{\text{new}} \tag{7}
\]

where \( E_{\text{new}} \) is the new electricity consumption, \( E_{\text{present}} \) is the current electricity consumption, \( A_{\text{present}} \) is the current office space and \( A_{\text{new}} \) is the new office space.

The rent cost is calculated as:

\[
C_{\text{new}} = \frac{C_{\text{present}}}{A_{\text{present}}} \times A_{\text{new}} \tag{8}
\]

where \( C_{\text{new}} \) is the new rent cost, \( C_{\text{present}} \) is the current rent cost, \( A_{\text{present}} \) is the current office space and \( A_{\text{new}} \) is the new office space.
4. Results

In this section the results from the employee questionnaire, statistics from the access badges, meeting room statistics, the Matlab simulation as well as energy and cost reductions are presented. A sensitivity analysis is made on the probability of going to the office, which in turn will affect the probability of being present at the office a specific time. The sensitivity analysis regarding these probabilities is given in the Section 4.5. The results from the sensitivity analysis in regard to risk of overcrowding are presented in Section 4.5. Both analyses will be more deeply discussed in the section sensitivity analysis under discussion.

4.1 Employees’ estimation on working habits and thoughts on the work environment

The factors that the employees at Origo office find most important in contribution to a nice and productive work environment according to the employee questionnaire are; good lighting, quiet areas, different sizes of flexible meeting rooms, ergonomic work stations, good ventilation and temperature as well as comfortable and natural meeting places in the common areas.

The answers on the questionnaire also contain information about what kind of working environment the employees seem to need. The employees answered these questions by grading them on a scale between 1 and 7. 1 stands for “almost none” and 7 stands for “very much”. The following questions were asked in the questionnaire:

1. How important is it for you to work in a quiet and undisturbed environment?
2. How important is it for you to change working environment/place during the day?
3. How big part of your work is dependent of communication and corporations with your co-workers?

These are the results summarized calculated from the answers from 32 employees:

Table 1. Compilation of the employee questionnaire. The number after each question represents the number of employees answering that specific value on the scale.

<table>
<thead>
<tr>
<th>Scale value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Mean value</th>
</tr>
</thead>
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<td>0</td>
<td>3</td>
<td>3</td>
<td>8</td>
<td>10</td>
<td>8</td>
<td>5.55</td>
</tr>
<tr>
<td><strong>Question 2</strong></td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>3.32</td>
</tr>
<tr>
<td><strong>Question 3</strong></td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>5.23</td>
</tr>
</tbody>
</table>
To be able to draw a conclusion about what kind of work environment the employees seem to need and prefer a mean value of question (1) to (3) are calculated. The scale 1 to 7 now represent different types of office space designs where 1 represents an closed office design with individual offices for every employee and 7 represents an open office design, with more shared areas. Question (1) is asked in the opposite scale where 1 represents a closed office and 7 represent an open office. When calculating the mean value of the three questions the answer to question (1) is transformed to the same scale as the two other questions. Henceforth the answers to question (1) are used to calculate the total mean value 2,45. The mean value for all three questions is therefore 3,67.

When the employees were asked to estimate how much time in percent they spend in their individual offices during their time at the office the mean value calculated from the 32 answers was 67,8 percent with a distribution from 40 to 95 percent. The employees were also asked to estimate how many days per month they work outside the office. For an average month each employee works outside the office 7,4 days. That means that on a standardized day 8 persons out of 62 are not at the Origo office.

Table 2 shows what kind of office design the employees prefer. They were given the opportunity to choose one to three different choices that they preferred and this is the information compiled.

Table 2. Compilation of the employee questionnaire

<table>
<thead>
<tr>
<th>Type of workplace</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal office</td>
<td>65,3 %</td>
</tr>
<tr>
<td>Shared office 2-4 persons</td>
<td>21,0 %</td>
</tr>
<tr>
<td>Shared office 5-8 persons</td>
<td>2,30 %</td>
</tr>
<tr>
<td>Do not care</td>
<td>6,80 %</td>
</tr>
<tr>
<td>Do not know</td>
<td>4,60 %</td>
</tr>
</tbody>
</table>

4.2 Meeting room statistics

The statistics over the meeting rooms are calculated between 8 AM to 5 PM every weekday for two months, February and March 2015. Both the booking statistics and information from the employees’ perceptions are presented in this chapter. The meeting room booking statistics presents an indication of what room sizes that the employees utilizes the most.
Table 3 shows the different sizes and number of meeting rooms at Origo office and a compilation over how much the different sizes are used according to the meeting room booking statistics. The utilization percent column in table 3 shows the booking statistics for the meeting rooms between 8am and 5pm.

Table 3. Compilation of the meeting room statistics

<table>
<thead>
<tr>
<th>Size of meeting room</th>
<th>Number of meeting rooms</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 persons</td>
<td>4</td>
<td>14,2 %</td>
</tr>
<tr>
<td>6 persons</td>
<td>2</td>
<td>29,6 %</td>
</tr>
<tr>
<td>9 persons</td>
<td>2</td>
<td>16,8 %</td>
</tr>
<tr>
<td>12 persons</td>
<td>2</td>
<td>35,8 %</td>
</tr>
<tr>
<td>25-35 persons</td>
<td>1</td>
<td>29,2 %</td>
</tr>
</tbody>
</table>

From the employee questionnaire the employees were given the opportunity to choose up to three choices of the number of people usually participating in their meetings. Statistics from the question with 68 votes is compiled in table 4.

Table 4. Compilation of the employee questionnaire

<table>
<thead>
<tr>
<th>Persons usually attending a meeting</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4 persons</td>
<td>44,2 %</td>
</tr>
<tr>
<td>5-9 persons</td>
<td>25,0 %</td>
</tr>
<tr>
<td>10-14 persons</td>
<td>8,80 %</td>
</tr>
<tr>
<td>15-24 persons</td>
<td>13,2 %</td>
</tr>
<tr>
<td>25+</td>
<td>5,90 %</td>
</tr>
<tr>
<td>No answer</td>
<td>2,90 %</td>
</tr>
</tbody>
</table>

The two tables show that the employees probably uses bigger meeting rooms than they need and the optimal number and size of the meeting rooms can probably therefore be improved and less square meters can be used but still cover the same needs. For example table 3 shows that from the employee questionnaire the employees states that they by far the most are between 2 and 4 co-workers participating in meetings. At the same time, table 2 shows that the rooms suited for 4 persons are rarely used and the rooms suited for 12 persons are most commonly used.
4.3 Unique arriving employees

At the Origo office it is common to work from outside the office. Therefore it is of importance to estimate how many employees actually come to the office a specific day. The data obtained from the access badges makes it possible to approximate a normal distribution of the number of unique employees that attend the office. The normal distribution is used to randomly generate a number of employees that come to the office a specific day.

![Normal distribution of number of employees that comes to the office a standardized day, with a mean value of 47.75 employees attending](image)

Figure 3. Normal distribution of number of employees that comes to the office a standardized day, with a mean value of 47.75 employees attending

On the horizontal axis of figure 3 shows the number of different employees that was present at the Origo office some time during working hours one day. The vertical axis contains information about how many days per month a specific number of employees are attending the office. Figure 3 is based on data obtained from the employee’s access badges. From the data a mean value of number of different employees that attend the office some time during a workday is calculated to 47.75. The normal distribution means that it is most probably that 47.75 people attend the office and the probability decrease if you move further away from the mean value in both directions on the horizontal axis.
4.4 Employee attendance

The simulation in Matlab has been set to run for 222 days, which is approximately the number of workdays in one year. For every day a random number of unique employees is generated from the normal distribution. In this section the simulation based on the access badge data with mean value of 47.75 unique employees in attendance is presented. The simulation based on the mean value of 54 employees has the same appearance with a small offset upward on the vertical axis. The graph presented in this section has the purpose to illustrate the form and appearance of the attendance curve and therefore the graph for the mean value of 54 employees are not necessary.
The horizontal axis shows what time it is during the day. The vertical axis contains information about the number of employees present at the office on a specific time. The number of present employees is depending on the number of unique persons attending the office that day and the transition probabilities that contains information about how many employees arrive or depart to the office specific times during the day.

4.5 Ratio of occupancy and risk of overcrowding

Each ratio of occupancy has a corresponding risk of overcrowding between 6 AM to 10 PM. At other times the risk of overcrowding is not of importance. It is interesting to compare the varying ratio of occupancy and the corresponding risk of overcrowding. The reason for that is the final result of energy and cost reduction are dependent on what mean value is used in the normal distribution.
In figure 6 the horizontal axis shows the number of workspaces the office could be designed for. The vertical axis contains the probability of overcrowding the office and can be converted into percentage, where 1.0 is equivalent to 100 percent. The lines show a decreasing probability when increasing the number of workspaces.

![Figure 6](image_url)

**Figure 6. Risk of overcrowding for the simulations with mean value of 47.75 and 54 employees attending**

![Figure 7](image_url)

**Figure 7. Shows a more detailed view containing the same information as figure 6 zoomed in between 20 and 55 on the horizontal axis. For specific values, see Appendix A.**

### 4.6 Energy and cost reductions

Table 5 shows ratio of occupancy with the corresponding area if every workspace is 27 square meters, the electricity consumption based on the new office space and the
reduction of electricity per year, the rent based on the current rent per square meter per quarter. All parameters are linear to the current electricity consumption and rent.

Table 5. New values depending on the ratio of occupancy

<table>
<thead>
<tr>
<th>Ratio of Occupancy</th>
<th>Approx. square meter (m²)</th>
<th>Electricity consumption/year (kWh)</th>
<th>Rent/month (kSEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 %</td>
<td>999</td>
<td>8341</td>
<td>170</td>
</tr>
<tr>
<td>61 %</td>
<td>1026</td>
<td>8567</td>
<td>175</td>
</tr>
<tr>
<td>63 %</td>
<td>1053</td>
<td>8793</td>
<td>179</td>
</tr>
<tr>
<td>65 %</td>
<td>1080</td>
<td>9018</td>
<td>184</td>
</tr>
<tr>
<td>66 %</td>
<td>1107</td>
<td>9243</td>
<td>189</td>
</tr>
<tr>
<td>68 %</td>
<td>1134</td>
<td>9469</td>
<td>193</td>
</tr>
<tr>
<td>69 %</td>
<td>1161</td>
<td>9694</td>
<td>198</td>
</tr>
<tr>
<td>71 %</td>
<td>1188</td>
<td>9920</td>
<td>202</td>
</tr>
<tr>
<td>73 %</td>
<td>1215</td>
<td>10145</td>
<td>207</td>
</tr>
</tbody>
</table>

5. Office design proposals

With the chosen ratio of occupancy at 68 percent and corresponding risk of overcrowding between 0.3 percent and 0.6 percent three proposals are developed for the office design. The choice of ratio of occupancy was based on the standard ratio, a acceptable risk of overcrowding and an imaginable total office space. The first proposal, as stated in the purpose only take energy and cost reductions into consideration when developed and the other two proposals include factors such as the employee’s requests and opinions as well as energy and cost reductions.

5.1 Proposal 1: Open office space

This proposal is only considering the energy saving aspects for the office to lower the costs for both electricity, heating and rental costs with leads to less environmental impact. Other impacts should of course be taken into consideration for an optimal change in office design since several aspects must be taken into consideration for a pleasant working environment.

An open office design usually requires less space than both individual office designs and activity based office designs do. However there is a larger need for meeting rooms
and quiet rooms where employees can make phone calls and other activities requiring no disturbance. It also requires quiet areas for people in need of silent surroundings to be able to focus. In an open office design the different companies could be divided into different sections without losing the interaction between them. The open office design is the most area-efficient alternative for an office, but requires a change in behaviour and work process for the employees if they are used to individual offices. The new open areas are more reliant on responsiveness and respect between colleagues because most of the area is shared area. It is necessary for all employees’ to show respect towards their colleagues.

In this project it is supposed that in an open office design a workspace require 17 square meters. With a ratio of occupancy at 68 percent the new office space is 714 square meters.

5.2 Proposal 2: Activity based workplace

It is very important to focus on the employee's needs and requirements when designing an activity-based office to achieve successful results. It requires a lot of planning and organization to manage the process since transforming from individual offices to an activity based shared office requires changes in behaviour and work strategies for everyone involved. Everyone affected by the changes needs to adapt to the new work environment and the new changes, which is more difficult for people with set habits.

As mentioned before an open office design and more energy- and ventilation efficient installations can produce more efficient buildings since an open office design often requires less space compared to individual offices for every employee. Usually an activity-based workplace requires about 22 square meters per employee when calculating on a new, adjustable building. That is a decrease with 7-10 square meters from their current office where STUNS uses 27 square meters per employee. The square meter required for the office in this proposal is 924 square meters when the standard of 22 square meters per employee is used in the calculation for an activity based office design.

The activity based office design will contain different areas for different activities. Flexible meeting rooms will provide the employees the option to use meeting rooms for corporations, meetings and discussions requiring various co-workers. Working desks in different surroundings will offer work with office material and individual computer work. Quiet areas will be used for work requiring much concentration and no disturbance from other co-workers. Telephone rooms can be used for private or confidential calls with no disturbance.
5.3 Proposal 3: Individual office design

This proposal takes employees' opinions and suggestions for improvement into account while the focus on energy saving parameters still permeates the solution. The focus of this report has been to adapt the office to the employees’ attendance and work patterns, thus the office will be designed to utilize the facilities better.

The employee questionnaire shows that an individual office is highly appreciated among the employees’ and therefore this solution presents an office structure with individual offices. The office will be customized to the ratio of occupancy as well and therefore the individual offices will not be personal. A booking system will make it possible to plan the day at the office depending on what the employees’ are planning to do during the day. They can for example book an individual office for the entire day, or a meeting room if it suits the tasks better. When the office design is adapted to the ratio of occupancy with an acceptable risk of overcrowding the chance of not getting an office suited for the employee will be very small.

The idea of an office space based on the chosen ratio of occupancy with individual offices requires; flexible meeting rooms for both small and big meetings, open areas with more comfortable solutions, one or two private rooms for business or confidential telephone calls and a café/lunch room for spontaneous conversations and breaks.

The office design proposes a more flexible solution fulfilling different requirements from employees, a solution towards an activity based office but with the opportunity to work individually and undisturbed. At the same time it will require less area and therefore lower rent and electricity bill for the companies. The increase of utilization of the office can make the office more attractive for other companies working in the same area. They will be able to work both quiet and undisturbed, but at the same time have the opportunity to cooperate and discuss with companies working in the same area managing the same issues.

The meeting rooms will be adapted after the result of the meeting room statistic and from the employee questionnaire about how many people usually attending their meetings. A solution with size adjustable meeting rooms will make the office even more flexible and well utilized. The office will meet the needs for today as a modern, flexible and pleasant office with efficiency and sustainability as key concepts.

This solution will need lockers for work and personal items the employees can gather before they choose where to work. There is a risk of overcrowding when adapting the office to the optimal ratio of occupancy but the days that problem occurs those employees can use the meeting rooms as an office. There is also a risk in that employees might book an individual office even though they are not using it to insure that they won’t be without a workspace.
The new square meter that is required for the office in this proposal is 1050 square meters. A standard of 25 square meters per employee is used in the calculation for individual office design.

5.4 Electricity reductions and rent and ventilation cost reduction

In Table 6 the results of the different office design proposals are compiled. The electricity and the rent, ventilation, heating and cooling are presented monthly.

*Table 6. New values depending of choice of office design*

<table>
<thead>
<tr>
<th>Type of office design</th>
<th>Square meters required (m²)</th>
<th>Electricity use reduction (kWh/month)</th>
<th>Reduced rent, ventilation, heating and cooling (kSEK/month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open office</td>
<td>714</td>
<td>686</td>
<td>168</td>
</tr>
<tr>
<td>Activity based office</td>
<td>924</td>
<td>540</td>
<td>132</td>
</tr>
<tr>
<td>Individual office</td>
<td>1050</td>
<td>452</td>
<td>111</td>
</tr>
</tbody>
</table>

Table 7 shows how much each employee reduces the electricity and the rent, ventilation, heating and cooling cost. The electricity presented monthly and the rent, ventilation, heating and cooling are presented per quarter.

*Table 7. New values per employee depending of choice of office design*

<table>
<thead>
<tr>
<th>Type of office design</th>
<th>Reduced electricity (kWh/employee, year)</th>
<th>Reduced rent, ventilation, heating and cooling (kSEK/employee, month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open office</td>
<td>133</td>
<td>33</td>
</tr>
<tr>
<td>Activity based office</td>
<td>105</td>
<td>26</td>
</tr>
<tr>
<td>Individual office</td>
<td>88</td>
<td>21</td>
</tr>
</tbody>
</table>
6. Parameter sensitivity

The results vary depending on input parameters and choice of output parameters. In this section the parameters will be discussed and their impact on the result will be analysed.

6.1.1 Unique attending employees

The number of unique attending employees differs between the compiled data from the access badges and from the employee questionnaire. The use of access badges is reliable as long as the employees arrive one by one. Problems occur when employees arrive in pairs or group and only use one access badge to enter or when employees are let in by the reception.

The employee questionnaire had a response rate of 34 out of 64. The average of 54 unique attending was calculated based on the given answers. The result may have been different if the response rate was higher, assuming the employees who did not answer would increase or decrease the mean value significantly.

6.1.2 Transition probabilities

The transitions probabilities are based on the access badge data and may differ from the reality due to the same problem as the unique attending employees. The transition probabilities only coordinate the arrivals to and departures from the office. To estimate a more exact number of workspaces, the employees’ working habits are needed as well. This would be possible if all entrances to meeting rooms and personal offices were registered.

6.1.3 Choice of risk

When deciding acceptable risk of overcrowding we need to evaluate the different sources of data and decide which source is more trustworthy and reliable in this context. From the access badge statistics we get an average of 47 unique attendings per day and from the employee questionnaire we get an average of 54 unique attendings per day. That is an increase of unique attendings with almost 15 %.

Appendix A and Appendix B shows number of workspaces with corresponding risk of overcrowding and ratio of occupancy based on both sources of unique attendings per day. We set the risk of overcrowding to a value between 0.3 percent and 0.6 percent depending on what mean value of unique attending employees we use. The ratio of occupancy stays on 68 percent in both cases, which is a suitable ratio of occupancy based on the employees’ presence. With a mean value of unique employees at 47 persons the risk of overcrowding is 0.3 percent which means that out of 222 work days the Origo office would be overcrowded 0.7 days. That means that the office would not
be overcrowded even once a year. If we only had one source of data for the risk of overcrowding and the mean value of 47 unique employees it would have been possible to increase the risk of overcrowding to about one percent and decrease the ratio of occupancy to 61 percent. However, that is not the case here. Since we have two sources of information to consider about the unique employees in this case, the two values would give us different risks for overcrowding and we decided to choose a ratio of occupancy that does not correspond to a to high risk in either cases. A ratio of occupancy of 68 percent is also a choice close to the standard of ratio at 70 to 80 percent.

Choosing a lower ratio of occupancy may result in a higher risk of overcrowding, and lead to dissatisfied employees and inefficient work. A higher ratio may increase the risk of not improving the utilization rate and may result in no cost- and energy improvements. The decision about which ratio to use are a balance between risk of overcrowding and the benefits of electricity, ventilation, heating, cooling and cost reductions.
7. Discussion

7.1 Discussion of the main results

With different sources of information it is important to estimate how reliable each source is and how they are related to each other. A comparison makes it clear if they match, and if the results are reasonable in their context. It also makes the results more reliable with information from various sources and makes the study more credible. The combination with statistics from the employees’ access badges, meeting room statistics, electricity consumption data, rent and ventilation bills together with the employees’ estimation through the questionnaire gives us a good foundation for our survey.

We get an indication from our research that the office space in its current situation is not well utilized. To increase the utilization the office space needs to be adapted to the ratio of occupancy. That would lead to a better utilization, less office space required and lower rent for each individual company as a positive consequence.

To compile results from how the meeting room are utilized we need to use both the meeting room booking statistics and the employee questionnaire. From the employees’ answers the conclusion can be drawn that there most often are between 2-4 colleagues attending each meeting. The meeting room booking statistics shows that the rooms suited for about 12 colleagues are used the most, not the small meeting rooms suited for the common small meetings. From the employee questionnaire and interviews we can assume that the employees more often book a bigger room than they need for reasons like better ventilation, more windows etc. It is also possible that employees that use the smaller meeting rooms do not feel the need to use the booking system. That makes the structure of the current meeting rooms rather ineffective. To adapt the meeting rooms better for the employees’ needs and utilization will optimize the usage at the same time as its more space efficient.

The three proposals presented are results from the employee questionnaire, suitable risk of overcrowding the office and optimal ratio of occupancy. The factors that the employees emphasized are important in contributing to a pleasant working environment such as good lighting, quiet areas, different sizes of flexible meeting rooms, ergonomic work stations, good ventilation and temperature as well as comfortable and natural meeting places. These factors are assumed given the same opportunity in all proposals.

A rough estimation about what kind of office space the employees required was made with information from the employee questionnaire. From the questionnaire we can extract what the employees consider and expect for a future office design and implement those opinions in our proposals. The questionnaire contained for instance three questions where the employees could rank their answer on a scale from 1 to 7. The
compilation of the answers results in a mean value of 3.67. (See section 4.1 for the specific questions) The estimation about type of office design can be made when the mean value is put in a context together with the scale 1 to 7 where 1 represents a closed office design with individual offices for every employee, and 7 represents an open office design, with shared areas. The mean value of 3.67 can be interpreted as that the employees have a need for communication between co-workers. But also spontaneous and informal meeting have a need for a quiet and undisturbed environment. The employee questionnaire also contains information about the employees’ estimations about how much time they spend in their individual office during a day at Origo office. The results showed a mean value of 67.8 percent and a distribution between 40 and 95 percent which shows that time spent in the individual office differs a lot between different people. Depending on what kind of work you are doing and your personal preference you may choose to spend more or less time in your individual office.

It is possible to meet these requirements for a new office with different solutions. In an activity-based workplace there are opportunities to choose your workplace according to what kind of work you are doing and what environment the work requires. In an individual office design it is important to have well planned meeting spots where co-workers can exchange ideas and talk more freely. An open office design needs to offer the employees the option of a quiet and undisturbed working environment where they can concentrate and make phone calls.

With regards to the electricity and cost reductions the open office design seems to be the best proposal. Since this project uses a linear relationship between the electricity and cost reduction and square meters the proposal with the lowest number of square meters required is equivalent with the lowest cost and lowest electricity consumption. To be able to draw a conclusion about which office design is best suited for the Origo office more information about the employees’ social habits, work patterns, needs and type of work is necessary.

7.2 Different office design and sustainable development

The project suggests three different proposals for the office design. The reason is that we do not have sufficient information about which type of office design would be best suited for the Origo office. The office design needs to encourage the employees’ productivity and wellbeing. It would be interesting to thoroughly investigate which type of office design favours the Origo office. To be able to do this development of the project more information about employee work patterns needs and type of work would need to be acquired along side with a deeper knowledge about office design and behavioural science. It would also be interesting to examine how a transition from individual office to another office design would work. As mentioned in section 3.3 it is important to involve the employees in the transition and have a thoroughly investigation
about the workplace and the employees behaviour to rely on when making the transition.

Changing an office design is a process containing many different decisions and several different steps. A meeting with Vasakronan gave us their model of the process from planning and discussing to decisions and complete results. The importance is the long-term perspective and what kind of different work places that will fulfil the company’s needs. To thoroughly investigate the work process for the organization and question current solutions at the same time as proposing new solutions will lead to a more well justified office design.

A company can take many different ways to becoming more sustainable. This project focuses on how an examination about the employees working habits can contribute to a more sustainable working environment by reducing the electricity consumption and rent and ventilation costs when adapting the office after the ratio of occupancy. It is possible to take a different approach to the problem by looking for technology solutions that would reduce the electricity and ventilation costs. When combining these two approaches you would get a more exact insight on how much electricity and cost reduction could be achieved. For example an investment in a new ventilation system that is depending on number of employees present would be more energy efficient and reduce the costs. This combination of utilization and technology solution would be interesting to investigate in a larger project.

This project focused on the environmental aspect of sustainable development in terms of energy and cost reduction. It is important to remember that sustainable development are much more than just one aspect. To have efficient and inspirational work environment can also mean that a company works with sustainability. If the employees enjoy and thrive in their workplace they are probably more productive and less inclined to need a long sick leave. It is also not for certain that energy efficient solution always favours sustainable development. For example if the energy efficient solutions implementation leads to an increase in energy use somewhere else in the company. For the energy efficient improvement to benefit sustainable development it is up to management and employees to continue making choices that follows the sustainable development definition.

### 7.3 Future scenarios

One important aspect when planning the office structure based on the ratio of occupancy is to try to estimate different future developments. It is of importance to investigate different possible effects in change of behaviour and attendance from the employees when changing the office design. For example, one consequence when changing the office design to activity-based workplace is that people attend the office earlier in the mornings to have the possibility to choose their workspace. That can
change the ratio of occupancy over the day and therefore a safety margin when choosing the risk of overcrowding need to be taken into consideration when designing the office. A positive effect with having a safety margin it that it can make the office design more sustainable over time. The future may lead to new development, for example an increase of employees. A flexible office design that can handle and facilitate different developments are more sustainable than a design that needs new investment and restructure to be able to facilitate the changes. Of the different proposals this project produced are some more equipped to handle change and future development. An individual office design would demand a much larger investment to be able to facilitate an increase in employees or a change in working behaviour than activity based workplace and an open office space.

With previously knowledge about innovation management and business cluster we can make the assumption that the office square meters is very valuable and space-efficient solutions is highly requested in terms of sustainable economical and environmental aspects. The importance for companies to be in innovative surroundings, surrounded by companies and people working in the same area, clusters, makes the office areas more attractive and therefore often more expensive. This makes it even more important to make sure that the utilization rate is high for it to be financially sustainable. The business clusters are often located close to big cities, to be close to the market, innovations and creative people and accessible for a lot of people. Today the urbanization together with the importance of small distance between companies working in the same area and big cities in need for the innovation makes space efficiency important and will most likely increase over time.
8. Conclusion

With the chosen risk of overcrowding the ratio of occupancy at 68 percent leads to an optimal office design containing 42 workspaces. Depending on which unique attendance that is used, the risk of overcrowding is between 0.33 percent and 0.64 percent, which is considered as a low and is therefore an acceptable risk.

By adapting the office to the ratio of occupancy in the different proposals leads to different monthly reductions in electricity and costs. Proposal 1, an open office design, would lead to an electricity reduction of 686 kWh and a cost reduction of 168 kSEK. Proposal 2, an activity based workplace, would lead to a 540 kWh reduction and a reductions of costs of 132 kSEK. The last proposal, proposal 3, an individual office design, would lead to an electricity reduction of 452 kWh and a cost reduction of 111 kSEK per month.

All of these values are according to our calculations with the assumption that both rent and electricity consumption is linearly correlated with approximated square meters for the different office designs.

For optimal utilization regarding square meters, electricity and costs, design proposal number one for open office space is the best alternative because it requires least square meters for the same ratio of occupancy and workspaces. But when considering more aspects about work habits, employees’ opinions and behaviour the optimal office design may need a different structure.
9. References

9.1 Literature


9.2 Online Publications


http://www.orsa.se/wk_custom/documents/%7B9c201840-69cd-4af6-92d7-40f0775ce226%7D_energikostnader.pdf (hämtad 2015-04-11)

9.3 Personal Interviews

Interviews with David Börjesson, project leader at STUNS Energy
Uppsala Science Park, 2015-03-26

Interview with Christina Frimodig, CEO at STUNS
Uppsala Science Park, 2015-05-06

Interview with Karin Boberg, Vasakronan
Dragarbrunngatan 50, 2015-05-11

9.4 Web Sites

Abilitypartner, *Framtidens kontor och arbetssätt*
http://www.abilitypartner.se/konferenser_kurser/framtidens-kontor-och-arbetssatt/ (Hämtad 2015-04-21)

Arbetsmiljöverket, *Hur trångt får det vara?*
Arbetsmiljöverket, temastor, kontor, förebyggande, olika typer av kontorslokaler  
http://www.av.se/teman/kontor/forebyggande/kontorslokaler/?AspxAutoDetectCookieSupport=1  
(hämtad 2015-04-23)

Arbetsmiljöverket, Kontor, Olika typer av kontorslokaler  
http://www.av.se/teman/kontor/forebyggande/kontorslokaler/?AspxAutoDetectCookieSupport=1  
(hämtad 2015-04-23)

Clarius, Activity based office  
(hämtad 2015-04-23)

Det nya arbetslivet, Arkiv, Mars 2014  
http://www.detnyaarbetslivet.se/2014/03/27/aktivitetsbaserad-kontor-arbetssatt/  
(hämtad 2015-04-23)

European Commission, Energy efficiency directive  
(hämtad 2015-04-08)

Forskning, Nyheter, Redaktionella artiklar, Ett idealiskt kontor är skräddarsytt för ändamålet  
http://www.forskning.se/nyheterfakta/nyheter/redaktionellaartiklar/ettidealisktkontoras  
kraddarsyttforandamalet.5.6569f5741369c37dd75d3.html  
(hämtad 2015-04-23)

Inc, Lead, Productivity  
http://www.inc.com/jim-belosic/3-reasons-the-open-office-concept-is-good-for-leaders.html  
(hämtad 2015-05-07)

Kontor och kontorslandskap 2013, individuella kontorsrum och delade kontorsrum  
http://kontorslandskap.se/individuella-kontorsrum-och-delade-kontorsrum/  
(hämtad 2015-04-23)

Kontor och kontorslandskap 2013, kontorslandskapets fördelar och nackdelar  
http://kontorslandskap.se/kontorslandskapets-fordelar-och-nackdelar/  
(hämtad 2015-04-23)

Miljö och utveckling 2015, ämnen, engagemang  
http://miljo-utveckling.se/varderingsstyrda-bolag-mer-lonsamma/  
(hämtad 2015-05-05)
Prevent, Arbetsliv, Artikelserie, Nya arbetsformer kräver nya kontor
http://www.prevent.se/Arbetsliv/Artikel/Artikelserie/Gilla-jobbet/Nya-arbetsformer-kraver-nya-kontor/
(hämtad 2015-04-23)

STUNS, Om oss
http://www.stuns.se/en/in-english.aspx#.VSuv8yjDKQk
(hämtad 2015-04-20)

Vasakronan 2015
http://en.vasakronan.se/
(hämtad 2015-04-19)

Vasakronan, kontorsinspiration
http://vasakronan.se/den-smartaarbetsplatsen/aktivitetsbaserat-kontor
(hämtad 2015-04-23)

Vasakronan, pressklipp
http://vasakronan.se/pressklipp/vasakronan-hyr-ut-1-700-kvadratmeter-till-stuns-i-uppsala-science-park-fastighetstidningen-se
(hämtad 2015-05-02)

Vasakronan, Artikel, hur stor kontorsyta behövs
http://vasakronan.se/artikel/hur-stor-kontorsyta-behovs
(hämtad 2015-05-06)

9.5 Other references

STUNS, Årssammanfattning av elanvändning 2014

STUNS, hyresavi kvartal 2 April-Juni 2015, 2015

Formel och tabellsamling för grundkursen sannolikhet och statistik. Uppsala universitet - matematiska institutionen. HT 2013
Appendix A

Table A1. Number of workspaces with corresponding risk of overcrowding and ratio of occupancy

<table>
<thead>
<tr>
<th>Workspaces</th>
<th>Risk of overcrowding</th>
<th>Ratio of occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>1,86 %</td>
<td>60 %</td>
</tr>
<tr>
<td>38</td>
<td>1,29 %</td>
<td>61 %</td>
</tr>
<tr>
<td>39</td>
<td>0,86 %</td>
<td>63 %</td>
</tr>
<tr>
<td>40</td>
<td>0,65 %</td>
<td>65 %</td>
</tr>
<tr>
<td>41</td>
<td>0,43 %</td>
<td>66 %</td>
</tr>
<tr>
<td>42</td>
<td>0,33 %</td>
<td>68 %</td>
</tr>
<tr>
<td>43</td>
<td>0,25 %</td>
<td>69 %</td>
</tr>
<tr>
<td>44</td>
<td>0,18 %</td>
<td>71 %</td>
</tr>
<tr>
<td>45</td>
<td>0,11 %</td>
<td>73 %</td>
</tr>
</tbody>
</table>

Table A2. Number of workspaces with corresponding risk of overcrowding and ratio of occupancy

<table>
<thead>
<tr>
<th>Workspaces</th>
<th>Risk of overcrowding</th>
<th>Ratio of occupancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>6,56 %</td>
<td>60 %</td>
</tr>
<tr>
<td>38</td>
<td>4,52 %</td>
<td>61 %</td>
</tr>
<tr>
<td>39</td>
<td>3,07 %</td>
<td>63 %</td>
</tr>
<tr>
<td>40</td>
<td>1,95 %</td>
<td>65 %</td>
</tr>
<tr>
<td>41</td>
<td>1,16 %</td>
<td>66 %</td>
</tr>
<tr>
<td>42</td>
<td>0,64 %</td>
<td>68 %</td>
</tr>
<tr>
<td>43</td>
<td>0,32 %</td>
<td>69 %</td>
</tr>
<tr>
<td>44</td>
<td>0,17 %</td>
<td>71 %</td>
</tr>
<tr>
<td>45</td>
<td>0,09 %</td>
<td>73 %</td>
</tr>
</tbody>
</table>
Appendix B

Employee questionnaire

Vårt syfte med den här enkäten är att undersöka er arbetsrutiner och utnyttjande av kontorslokalerna.
Svaren behandlas anonymt!

1. Hur ser en typisk arbetsvecka ut för dig? Fyll i ungefärliga tider för när du anländer till kontoret och när du lämnar kontoret de olika dagarna. t.ex. 08.30-17.00 måndag:
tisdag:
onsdag:
torsdag:
fredag:

2. I snitt hur många dagar per månad arbetar du utanför kontoret? T.ex. hemifrån, ute hos kund, resor osv

3. a) Mellan vilka tider äter du vanligtvis lunch?
b) Hur många gånger i veckan äter du din lunch i lunchrummet?

4. Hur stor andel av din arbetstid på kontoret spenderas i ditt personliga arbetsrum?
Svara i procent:

5. Hur många personer brukar medverka vid era olika möten? Markera högst tre alternativ

2-4
- 5-9
- 10-14
- 15-24
- 25+

6. Hur stor del av ditt arbete är beroende av kommunikation/samarbete med kollegor på kontoret?
Skala 1-7

7. Hur stort är ditt behov av att arbeta i ostörd och tyst omgivning?
Skala 1-7

8. Hur stort är ditt behov av att byta arbetsmiljö/-plats under dagen?
Skala 1-7

9. Vad föredrar du? Markera högst två alternativ

- Personligt arbetsrum
- Arbetsrum innehållandes 2-4 medarbetare
- Halvöppet landskap med 5-8 medarbetare
- Öppet landskap
- Spelar ingen roll
- Övrigt

10. Finns det något du saknar på ert nuvarande kontor?

11. Skriv några faktorer som du tycker bidrar till en bra kontorsmiljö och arbetsplats