The influence of Smart Buildings upon the wellbeing and productivity of office workers

Version 01, 18th June 2020

Prof. Dr. Michael Krödel

IGT - Institut für Gebäudetechnologie GmbH
Alte Landstrasse 25, 85521 Ottobrunn, Germany
www.igt-institut.de · *info@igt-institut.de*

Contents

1 Introduction

For office-based businesses, the cost of labour represents the largest operating cost by far. For knowledge-based companies, it represents approx. 90% of the budget compared with approx. 1% spent on energy (Illustration 1).

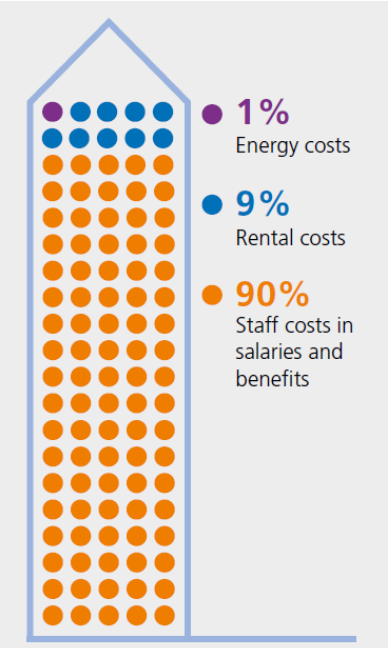

Illustration 1: operating costs of knowledge-based companies [WGBC 2014]

Therefore it goes without saying that employee productivity is the foremost priority. Next to personnel management, working atmosphere and remuneration, the quality of the workplace emerges as a key factor . A study involving more than 7.000 people from 12 nations indicates that more than 50% of those interviewed stated that the quality of their workplace has a direct effect upon their productivity [JLL 2017]. Smart Buildings can make a significant contribution by providing optimal air quality, lighting, thermal comfort and flexible interaction with a modern office environment. Scientific research demonstates that cognitive employee performance is clearly enhanced when compared with, for example, environments where ventilation and illumination are not regulated [Wargocki et al. 2000].

A Smart Building is much more than just a resource-optimised facility. „Smart Building“ is often used to indicate that a building uses less energy and lowers operating costs. This is correct – building automation pays for itself in the space of a few years and generates appreciable savings in running costs [Merz et at 2016]. However, the main benefit of such „Smart Buildings“ lies elsewhere – in the positive effects upon employee productivity, employee loyalty and employer attractiveness for new talents.

In 2009 Prof. Dr. Derek Clements-Croome from Reading University (UK) claimed that an „intelligent building“ should benefit energy efficiency and human wellbeing alike: *„an intelligent building caters for the needs of its dwellers, organisations and society alike. It must be sustainable in terms of energy and water consumption, with reduced emissions and waste – a healthy and functional environment for those who live and work there*“ [Clements-Croome, Yang 2018].

The influence of Smart Buildings upon the wellbeing and productivity of office workers

Smart Buildings can make an important contribution towards the wellbeing and productivity of those who work there. These aspects can therefore be expected to play a central rôle in the planning process for future commercial real estate projects [Xie et al. 2017].

We shall now more closely explore these parameters:

- Which opportunities exist for enhancing employee productivity and wellbeing within a Smart Building context?
- Which scientifically proven findings support such scenarios?
- What must be taken into account when planning a Smart Building?

Smart Buildings have far-reaching, positive effects. Motivated employees bring satisfied customers. Illustration 2 shows – on the one hand – the relationship between employee satisfaction, personal productivity and corporate success. On the other hand, employee satisfaction generates customer satisfaction and fosters trust between the customer and the employee's company. Interestingly, research shows that a dissatisfied employee has a direct, negative impact upon customer satisfaction – but not the other way around. A dissatisfied customer has a lesser impact upon employee satisfaction [Jeon&Choi 2012].

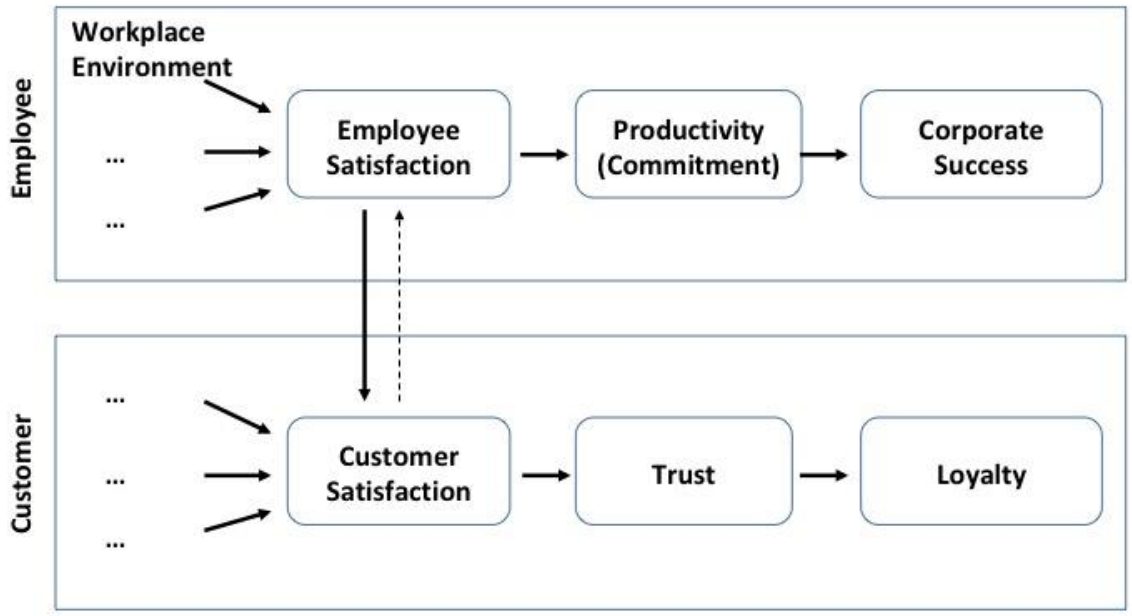

Illustration 2: Effects of employee satisfaction [Jeon&Choi 2012]

2 Employee productivity and the working environment

„The workplace is more than just a piece of real estate.
It's a living organism that enables people and companies to bring life and work together in a positive and constructive way." [1]

This chapter illustrates the many possibilities offered by a Smart Building for enhancing employee satisfaction whilst improving productivity and customer satisfaction.

2.1 The influence of the working environment upon employee satisfaction

2.1.1 Air quality

The importance of adequate air quality and its relevance to human wellbeing has been known for a long time. In 1858, Dr. Max von Pettenkofer published his book titled „Über den Luftwechsel von Wohngebäuden" („Ventilation in residential buildings") and wrote that adequate air quality requires carbon dioxide levels – defined as carbonic acid at the time – below 1/1000 parts. In modern terms, that equates to a CO_2 concentration of 1.000 ppm (parts per million). This so-called „Pettenkofer-Number" was used for a long time as key criterium for the quality of the air within closed spaces.

"These tests prove that air does not become us well when breathing and perspiration raise carbonic acid levels beyond 1 part to a thousand. We can rightfully claim that air is unsuitable for constant breathing when breathing and perspiration raise carbonic acid levels beyond 1 part to a thousand." [2]

The direct effects of indoor air quality upon human health have been thoroughly analysed. Studies conducted in 2006 and 2008 have shown that performance (defined as speed of work at a standardised error rate) increases by between 8 % and 14 % when the fresh air intake rate is doubled (e.g. increased from 17 m³/h to 34 m³/h) [Wargocki 2008].

A survey canvassing more than 1.200 workplaces revealed that there is a direct relationship between the quality of office air and employee satisfaction. A CO_2 threshold value of 582 ppm was identified – most employees complained of bad air quality with carbon dioxide loads exceeding this value [Park et al. 2019].

2.1.2 Light

Light has a significant impact upon the human psyche. It influences the „inner clock" and directly affects performance and wellbeing. In 2002, researchers discovered that the known retinal light receptors in the human eye are complemented by retinal ganglion cells containing melanopsin. These cells influence the production of melatonin, also known as the „sleep hormone". This interaction is known as the melanopic effect. This explains why we are more active/restless in the presence of „cold" light and more relaxed in the presence of „warm" light. Constant exposure to stress-provoking types of light can lead to health-damaging conditions – therefore, the question arises: which is the most suitable type of light for specific working conditions?

[1] Dr Marie Puybaraud, Global Head of Research, JLL Corporate Solutions
[2] Dr. Max von Pettenkofer

The angle of incidence of the light falling upon the photosensitive retina is of primary importance for the melanopic effect. The ganglion cells (containing melanopsin) are situated in the lower section of the retina. Ideally, light should enter the eye at an angle between 0° and 45° when the eye is looking straight ahead (Illustration 3). Light can be emitted directly from electric lights, or be reflected by walls and office furniture.

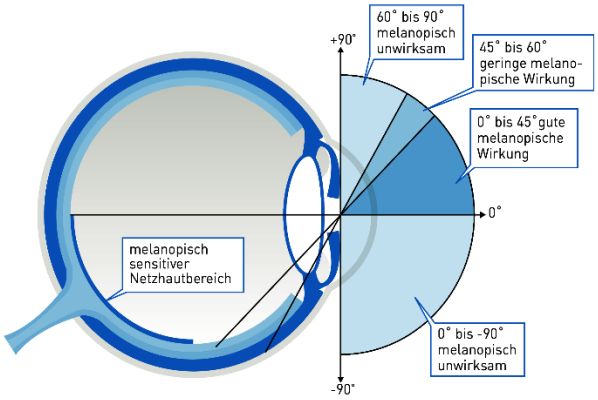

Illustration 3: Angle of incidence of light required for the melanopic effect [www.trilux.com]

The spectral range of white light - defined as „colour temperature“ and measured in Kelvin (K) units - ranges from „warm white“ (e.g. with 2.700 K) to „cold white“ (with over 6.000 K). Ideally, artificial lights can be individually adjusted to obtain the appropriate colour temperature. This technical feature is normally titled „tunable white“. When this feature is used to adjust colour temperature throughout the day in order to enhance human wellbeing, we speak of HCL (Human Centric Lighting) or, less specifically, biologically effective lighting.

Altogether, workplace lighting influences wellbeing in the office as well as the quality of sleep at home. Restful sleep is an important factor for fitness and working performance, and fundamentally important for workplace safety. A lack of natural light and excessive exposure to artificial light, especially „cold“ light, can lead to disturbed sleep and fatigue as well as as poor concentration which, in turn, can increase the risk of accidents as well as depression and cardiometabolic illness [Kantermann et al. 2018].

Of course, office space lighting plays a partial rôle upon employee wellbeing – after work, other conditions in public and private spaces prevail. Still, the quality of artificial lighting over a period of many hours every working day is a prominent factor.

2.1.3 Thermal comfort

Thermal comfort as defined by the DIN 1946-2:1994 norm implies that air temperature, air humidity, air circulation and solar warming is perceived to be ideal without having to resort to additional warm, cold, dry or humid air.

Thermal comfort depends upon several influencing factors. One’s own body heat plays a rôle, and depends upon the type of task being performed. Here, the possibility of dissipating heat must be taken into account. Here, several factors play a decisive part: air temperature, temperature of boundary spaces, air speed, air humidity and clothing worn. These variables mean that there is no such thing as a single

ideal condition. A comfort zone has been defined where most persons claim to feel comfortable. Taking temperature and humidity into account, this comfort zone can be defined using the so-called „h,x diagram“ or „Mollier diagram“ (Illustration 4) [Dentel&Dietrich 2006]. In simple terms, thermal comfort is given when air temperature ranges from 22°C to 26°C with relative air humidity levels between 35% and 65%.

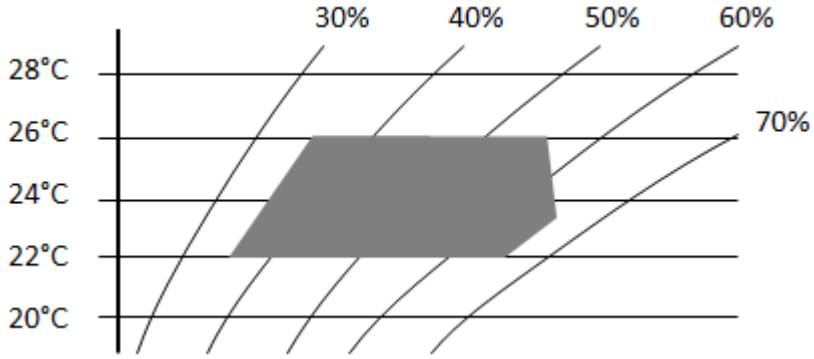

Illustration 4: Thermal comfort relative to air temperature (in °C) and relative air humidity (in %) [Dentel&Dietrich 2006]

The temperature of walls and ceiling should not differ greatly from ambient air temperature in order to avoid subjective discomfort. Rooms should be heated in such a way as to avoid appreciable differences in the temperature of walls, ambient air and the surfaces of heating appliances such as radiators.

Thermal comfort plays a decisive rôle in workplace wellbeing and employee productivity. Research conducted in 1986 supplied evidence that there is a clear relationship between rising temperature and sinking physical and psychological performance. At 28 °C, physical performance drops by 50 % whilst psychological performance suffers a 20% loss [Dentel&Dietrich 2006], [Wyon 1986]. Further research demonstrates that a rise in temperature from 23 °C to 26 °C increases efficiency by 50%. As of 29 °C – i.e. at excessive ambient temperatures – efficiency drops to the same levels experienced at 23 °C [Wyon et al. 2001].

2.1.4 Modern office environments

Another important factor is the flexible use of office space within Smart Buildings, with varying office furniture configurations as well as a mix of large open-plan areas and meeting rooms, plus communal spaces. Evolving work processes (team structures, procedures etc.) call for ongoing optimisation. A Smart Building can monitor and evaluate the utilisation of available spaces and supply data enabling the smart management of limited resources.

Only a true „smart building“ can adapt itself to the real needs, preferences and evolving user behaviour of its occupants. Be it through „smart“ facility management systems or, indirectly, by gathering occupancy-related data that can supply a solid base for space and equipment planning.

When Smart Building facility users have more influence upon their workspace environment, e.g. by adjusting climate and lighting according to personal preference, this invariably leads to better workplace satisfaction and higher productivity [WGBC 2014].

2.1.5 Personalised services and indoor navigation

The enhanced gathering and evaluation of facility-related data will result in more and more personalised services being offered. Employees can express personal preferences and generate a workplace profile (e.g. the vicinity to restrooms, lifts, communal areas and technical facilities). In combination with indoor navigation systems, employees enjoy better insight into the facility's structures and can reach their destination in unfamiliar locations far more quickly and comfortably. This is especially relevant in an environment where workspaces are continually being re-allocated to match changing requirements (especially in large corporations with many locations and where teamwork is subject to constant change).

Personalised services offer a wealth of enjoyable and useful features. At the same time, individual privacy must be protected. The balance between the corporate analysis of person-related data and the rights of the individual, or those of an organisation, must be taken into account. This is a challenge that must be met and constantly borne in mind, project by project.

2.2 The influence of employee satisfaction upon productivity

Illustration 2 in Chapter 1 shows the relationship between employee satisfaction and productivity. This is supported by the findings of many studies. The complexity of the interaction between many variables makes a quantification difficult, but there is clear evidence of the direct influence of employee satisfaction upon productivity.

A study conducted in 2000 [Clements-Croome&Kaluarachchi 2000] concluded that employee satisfaction can enhance productivity by up to 15%. In addition, a study involving two buildings was conducted. The findings revealed that a good workplace led to fewer illness-related absences and increased productivity. It became apparent that the employees who were most dissatisfied with their workplace were also those who suffered most from environment-related and task-related illness.

The connection between air quality and employee productivity has already been shown – doubling the fresh air intake rate in office facilities typically improves productivity by between 8 % and 14% (see Section 2.1.1).

A study commissioned by Steelcase Inc., Grand Rapids (USA) and conducted by the market research institute Ipsos S.A. (Paris) with more than 12.000 participants in 17 nations determined that the connection between employee commitment and employee satisfaction is one of the 5 key findings of the study. In detail, conclusive evidence of this link was supplied; enhancing workplace conditions was identified as key measure for fostering employee commitment. Most of those interviewed (still) work in individual, non-open-plan office spaces with fixed workspace allocation. However, the clear trend towards flexible workspace allocation means that the employee-friendly assignment of changing workspaces will gain increasing importance.

The „Human Spaces Report" indicates that a modern building can positively influence employee satisfaction by up to 15% and enhance productivity by 6% [HumanSpaces 2015]. Although these improvements can vary from building to building, it's clear to see that there is a tangible link between employee satisfaction and productivity.

These findings are confirmed by another survey conducted 2002 in The Netherlands. This data quantifies various parameters and clearly shows their impact upon productivity and absences from work (Table 1).

	Higher productivity	Reduced absences
Good interior fittings	10 % - 15 %	2,5 %
Clean air	3 % - 7 %	1,5 %
Adequate rate of air exchange	1 % - 2 %	0,5 %
Adjustable room temperature	2 % - 3 %	0,5 %
Adequate room temperature	ca. 7 %	n.a.

Table 1: Impact upon productivity and absences from work (extract from [Leijten 2002])

3 Conclusions

3.1 The influence of Smart Buildings upon employee wellbeing

All in all, it can be clearly demonstrated that a Smart Building fosters employee satisfaction and enhances productivity. Many factors influencing employee wellbeing – e.g. ambient air quality, intelligent lighting, advanced thermal comfort and the features of a modern office environment – give the Smart Building a clear advantage.

A mentioned earlier, knowledge-based companies spend approx. 90 % of their budget on their personnel. Therefore, a Smart Building not only contributes towards energy efficiency – it makes a large contribution towards overall corporate success.

3.2 Smart Buildings need timely planning

„Some people plan in order to avoid failure. Others fail because they don't plan." [3]

A further conclusion: Smart Building requirements must be taken into consideration at the planning stage. The main criteria which are relevant to employee satisfaction in a Smart Building context are straightforward in substance, and can be reliably taken care of without incurring large expense.

Unfortunately, most builders still tend towards doing things „the good old way", e.g. using empirical data and methods from past experience. Such thinking sees additional requirements as a disturbance, despite the ease with which they could be taken into consideration.

Building contractors, investors and tenants in need of a modern office facility require innovation-friendly planners. They are not hard to find. A key criterium for the birth of a new Smart Building is the early integration of such planning experts within the project team context.

Another key aspect is the timely planning of the necessary sensor networks. They supply the Smart Building with essential data on occupancy patterns as basis for real-time building management and control, as well as for analytical purposes.

[3] Peter E. Schumacher, publicist

4 Sources

[CIB 2018]	CIB Commission W098; Intelligent and Responsive Buildings; 2018
[Clements-Croome 2018]	Clements-Croome D.; Creating the Productive Workplace (3rd Edition); 2018
[Clements-Croome&Kaluarachchi 2000]	Clements-Croome, D., Kaluarachchi Y.; Assessment and measurement of productivity; 2000
[Clements-Croome&Yang 2018]	Clements-Croome D., Yang T.; CIB Commission W098 - Intelligent and Responsive Buildings Roadmap; 2018
[Dentel&Dietrich 2006]	Dentel, A., Dietrich, U.; Thermische Behaglichkeit – Komfort in Gebäuden; 2006
[Ghaffarianhoseini et al. 2016]	Ghaffarianhoseini A., Berardi U., Al Waer H., Chang S., Halawa E., Ghaffarianhoseini A., Clements-Croome D.; What is an intelligent building? Analysis of recent interpretations from an international Perspective; 2016
[HumanSpaces 2015]	Human Spaces; The Global Impact of Biophilic Design in the Workplace; 2015
[Jeon&Choi 2012]	Jeon H., & Choi B.; The relationship between employee satisfaction and customer satisfaction (Journal of Services Marketing); 2012
[JLL 2017]	JLL Corporate Solutions; Global Report on „Workplace powered by human experience"; 2017
[Kantermann et al 2018]	Kantermann T., Schierz C., Harth V.; Gesicherte arbeitsschutzrelevante Erkenntnisse über die nichtvisuelle Wirkung von Licht auf den Menschen. Verein zur Förderung der Arbeitssicherheit in Europa e.V. (VFA); 2018
[Leijten 2002]	Leijten J.; Binnenmilieu, productiviteit en ziekteverzuim (The inside environment, productivity and sick leave); 2002
[MacNauthon et al 2018]	MacNaughton P., Cao X., Buaoncore J., Cedeno-Laurant J., Spengler J., Bernstein A. Allen J.; Energy savings, emission reductions, and health co-benefits of the green building movement; 2018
[Merz et al. 2016]	Merz H., Hansemann T., Hübner C.; Gebäudeautomation (Hanser Verlag); 2016
[Park et al. 2019]	Park J., Loftness V., Aziz A., Wang T.; Critical factors and thresholds for user satisfaction on air quality in office environments; 2019
[Steelcase 2016]	Steelcase Global Report; Mitarbeiterengagement und Arbeitsplätze in aller Welt; 2016

[Wargocki et al 2000]	Wargocki P., Wyon D., Sundell J., Clausen G., Fanger P.; The effects of outdoor air supply rate in an office on perceived air quality, Sick Building Syndrome (SBS) symptoms and productivity.; 2000
[Wargocki 2008]	Wargocki P.; Improving indoor air quality improves the performance of office work and schoolwork; 2008
[WGBC 2014]	World Green Building Council; Health, Well-being & Productivity in Offices; 2014
[Wyon 1986]	Wyon, D.P.; The effect of indoor climate on productivity and performance, revised version of a Swedish publication in VVS & Energy; 1986
[Wyon et al. 2001]	Wyon, D.P., Andersen J., Lundquist G.R.; The effect of moderate heat stress on mental performance, Chapter 16 in Indoor Air Quality Handbook; 2001
[Xie et al. 2017]	Xie, H., Clements-Croome, D., & Wang, Q.; Move beyond green building: A focus on healthy, comfortable, sustainable and aesthetical architecture; 2017