

## **Productivity**

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# Productivity

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## INTRODUCTION

According to the Oxford English Dictionary, (economic) productivity means the effectiveness of productive effort, especially in industry, as measured in terms of the rate of output (e.g. goods, products, services) per unit of input (labour, materials, equipment, etc.). In scientific literature, productivity is comparably defined as the relationship between output and input, between results and sacrifices (Aronoff and Kaplan, 1995). Output can regard the number and quality of products, and the operating result, for example expressed as the net profit or market share. Input involves resources i.e. production factors such as labour, capital, technology, information and facilities. The total factor productivity is the ratio between the total output and total input (Frankema, 2003). If the ratio regards only a particular part of the input, it is called partial productivity. For example, labour productivity can be expressed as output produced per unit of labour (Christopher and Thor, 1993).

There are three ways to increase the ratio between output (the ‘numerator’) and input (the ‘denominator’) (Keizer and Eijnatten, 2000; Van der Voordt, 2003):

1. Producing more output with the same input (higher numerator, same denominator);
2. Producing the same output with less input (same numerator, smaller denominator);
3. Increasing the output more strongly than the input (proportionally, the numerator increases more than the denominator).

Productivity is naturally linked to effectiveness and efficiency. A work process is effective if the right things are being done: all activities contribute to achieving the established goals and purpose and the achieved result is as similar as possible to the intended result. Efficiency means doing things properly: the intended result is achieved with as few resources as possible. With respect to productivity, effectiveness is mainly linked to the output (the best possible results) whereas efficiency is linked to the input (as few resources as possible). The costs of buildings and facilities are typically considerably lower (10%) than the costs of staff (80%) (Hanssen, 2000). This implies that if productivity of knowledge workers can be encouraged by improving facilities, it is potentially very cost effective to do so.

This chapter will focus on labour productivity. First we will explore how to measure labour productivity. Then we will present a state of the art of current knowledge on the impact of facilities on labour productivity, including a conceptual framework that visualises the assumed influence of various variables on labour productivity and available empirical evidence of the impact of four physical characteristics of the work environment: physical conditions, space, ergonomics and aesthetics. Finally we will come up with a shortlist of Key Performance Indicators and suggestions for further research.

## HOW TO MEASURE PRODUCTIVITY

Nowadays the economy of developed countries is strongly based on the productivity of knowledge workers. In a knowledge society it is important not only to focus on the quantity but also to measure the quality of the outcomes (Blok et al., 2011). Measuring the productivity of knowledge workers - on organisational level, team level and individual level - is quite difficult (Davenport and Prusak, 2000). For instance: how to measure the contribution of employees to innovative ideas that resulted in larger profits, or how to measure the quality of a research report? Various organisations use inventive methods for measuring the output of their organisation. For example, some universities measure teaching productivity by the ratio between the number of students that have successfully completed a particular course component and the number of hours spent by lecturers (Van der Voordt, 2003). Research productivity is often being measured by means of the number of publications per FTE, with a weighting factor to take into account the scientific status and the impact factor of the publication. In spite of the rational ideas behind these systems, it likely evokes criticism due to its limited validity and reliability.

Because it is rather difficult to measure the productivity of knowledge workers, most studies on the impact of buildings, other facilities and services on labour productivity, measure the *perceived* (impact of facilities on) productivity. Besides, more objective measurement methods are being used, if possible at all. According to the literature on environmental psychology, corporate and public real estate management, facility management and business administration, the impact of the work environment can be measured in various ways (Van der Voordt, 2003; Sullivan, Baird and Donn, 2013):

- *Actual output versus actual input*. For example:
  - The number of translated words per team or per employee per unit of time (translation agency), the number of phone calls per day (call centre), or the number of manufactured cars per FTE (automobile industry).
  - The impact of facilities on the outcomes of cognitive performance tests (e.g. working memory, processing speed, concentration).
- *Actual input*, for example monitoring computer activity (keystrokes, mouse clicks) that is used to produce the output.
- *Amount of time spent or saved*, for instance the amount of time gained by implementing a new computer system which makes logging on less time consuming, or the opposite: the amount of time lost by having to log on frequently to a time consuming computer system.
- *Absenteeism due to illness* or for other reasons and as such being non-productive, or the opposite: *presence*. Connected topics include the reported frequency of health issues.
- *Satisfaction*, based on the assumption that a happy worker is a productive worker (Halkos and Bousinakis, 2010). Connected topics include job satisfaction, job engagement, satisfaction with facilities, or the intention to stay or to quit.
- *Perceived productivity support*, i.e. the perceived support of productivity by the current work environment, measured on a Likert scale (Vos and Dewulf, 1999; Maarleveld, Volker and Van der Voordt, 2009), the estimated percentage of time being productive

(Batenburg and Van der Voordt, 2008), the perceived productivity gain when all facilities would be excellent (Von Felten, Böhm and Coenen, 2015) or the perceived increase or loss of productivity after a change (Leaman and Bordass, 1997).

- *Indirect indicators.* For instance the extent to which people are able to concentrate properly, the frequency of being actually distracted, the easiness with which employees can solve a problem, or the lack of knowledge through insufficient interaction with colleagues.

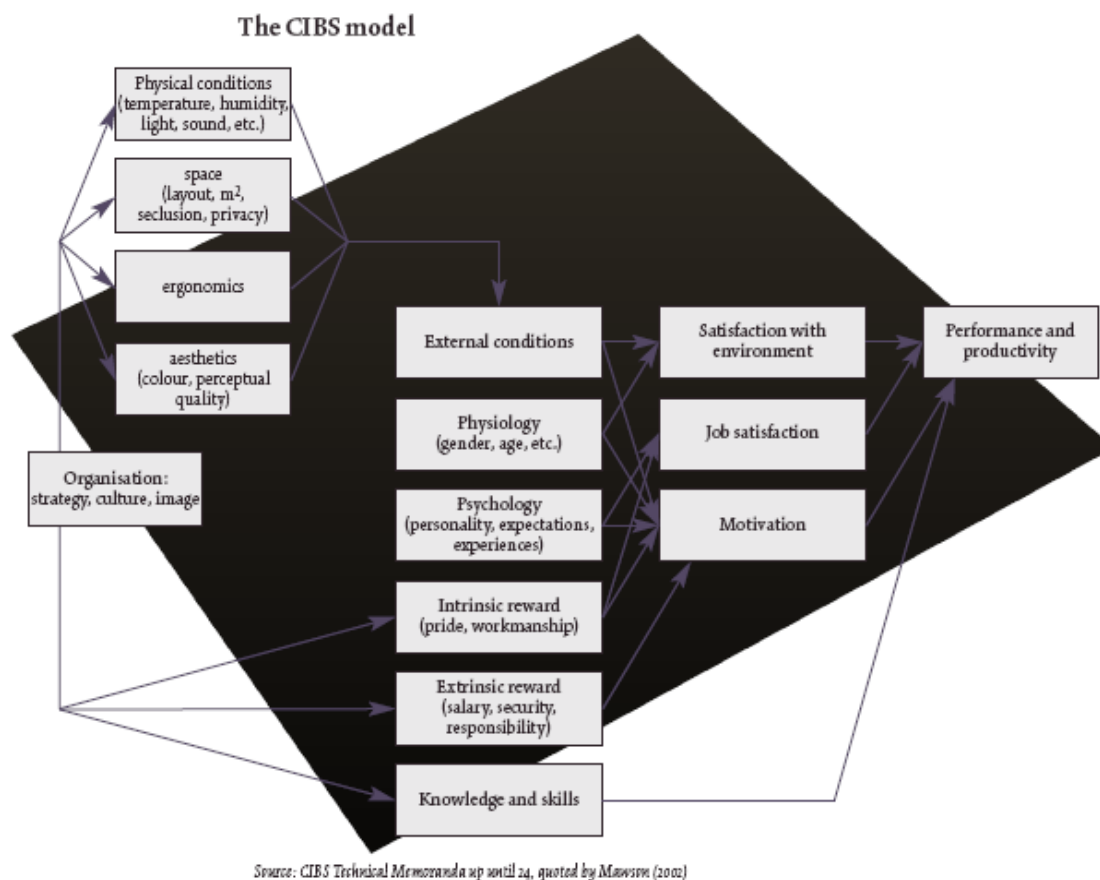
While some studies have found significant correlations between subjective and objective measures of performance (i.e. Oseland, 1999), these measures appear to be weakly correlated in general. Therefore, it is likely that self-reported and objectively measured productivity each measure different aspects of performance. After an extensive review, Sullivan, Baird and Donn (2013) suggest that occupant surveys are the best method to measure the influence of the work environment on productivity. An added benefit is that conducting surveys is a relatively time and cost efficient method. It seems the best option to ask occupants *directly* about the effect of the work environment on productivity. Objective methods can complement occupant surveys, especially if they measure important organisational outcomes such as absenteeism (Sullivan, Baird and Donn, 2013).

Whereas most people are able to indicate whether a specific environment has a positive or negative effect on their production, they find it difficult to define the exact *relationship* between their production (output) and particular resources used by the organisation (input). Defining cause-effect relationships is also difficult for researchers, especially when conducting field studies. In the period before and after an intervention such as a renovation, the introduction of New Ways of Working, or a new IT system, often other variables have changed as well, such as the composition of the staff, management style, or contextual factors such as the labour market or the economy. For this reason, some environmental psychology research is conducted in artificial settings. This makes it possible to isolate the impact of a single factor. However, findings cannot always be generalised to real life settings.

The complexity of measuring office occupiers' productivity is not only caused by the large number of possibly influential variables, but is also the result of the lack of a clear definition as to what actually constitutes an output in productivity terms. Office occupiers undertake a range of different activities and each activity may have its own specific output. Therefore, the start of understanding any productivity measure is to define the different work processes that are undertaken in the office environment (Greene and Myerson, 2011; Haynes, 2008). Work processes that are largely routine and repetitive, such as process working, lead to a more clearly defined output. This form of office output can lead to a more mechanistic measurement of office productivity such as output/input (Greene and Myerson 2011). Defining and measuring where and how knowledge is created and transferred in the office environment is a more complex issue (Oseland et al. 2011, Appel-Meulenbroek, 2014).

## THEORETICAL FRAMEWORK

Many authors tried to visualise the assumed impact of various variables and constructs on labour productivity. Most models confirm that many variables including buildings and facilities, work processes, organisational characteristics, personal characteristics and the external context may have an impact on labour productivity (Clements-Croome, 2000; Van der Voordt, 2003; Batenburg and Van der Voordt, 2008; Mawson, 2002; Haynes, 2007). In the CIBS model, it is assumed that in addition to many other variables, physical conditions, space, ergonomics and aesthetics have an effect on satisfaction with the environment, on motivation, on job satisfaction and consequently on performance and productivity, see Figure 1 (Mawson, 2002). In the next section we will use these four external condition factors to discuss empirical evidence of the relationship between the physical work environment and labour productivity.



*Figure 1: Impact of various variables on performance and productivity (Mawson, 2002)*

## EMPIRICAL EVIDENCE

According to Bakker (2014), to ensure a knowledge worker is optimally productive and happy, it is important that he or she can attain personal objectives and that facilities and services fit with personal needs. An appropriate physical environment should optimally facilitate different job activities, ranging from communication to concentration, informal and formal meetings, and different moods, from being calm and relaxed to being stressed or excited. Due to the possible impact of many different variables, it is rather difficult to define the relative importance of the external conditions compared to other factors. A recent study

showed that satisfaction with the organisation plays a more substantial role in the perceived productivity support of the work environment, than the office concept (layout and use) itself (De Been and Beijer, 2014). However, the office concept did have a significant effect on satisfaction with the work environment and perceived productivity support. Many studies came up with empirical data that confirm the assumed relationship between external conditions and productivity. For example, Batenburg and Van der Voordt (2008) revealed a significant correlation between satisfaction with facilities and the perceived support of productivity: the more satisfied with the facilities, the higher the rating of productivity support by the working environment. Further analyses revealed that both functional aspects and psychological aspects of the working environment – such as adequate privacy and an inspiring office design – positively affect the perceived support of labour productivity. The significance of the workplace is backed up by the research of Brill and Weidemann (2001), who after analysing a dataset with 13.000 respondents concluded that the physical workplace contributes 5% to individual performance and 11% to team performance. Another study came up with even higher impact figures of interventions that were undertaken at different organisations, including a productivity rise of 10 – 38% as a result of improved ergonomic furniture, an effect of 6-11% by improved lighting and an increase of 39% after implementing private offices, more comfortable chairs and advanced computer hardware (Kleeman et al., 1991). Based on 30 case studies, Kaczmarczyk et al. (2001) found productivity improvements of 2-58% after the introduction of teleworking, 15% due to high quality design, 22% due to ergonomic furniture, 9-13% due to high quality lighting and 7-10% due to noise reduction. Research undertaken by Barrett et al (2013) evaluated the impact of a physical classroom on the academic progress of 3,766 pupils from 153 classrooms in 27 schools. Using multilevel regression modelling they identified seven key design parameters that impacted on the students learning progress (Barrett et al. 2013). The seven factors were light, temperature, air quality, ownership, flexibility, complexity and colour.

### **Physical conditions: indoor climate, light, greenery and sound**

#### *Indoor climate*

An uncomfortable warm or cold temperature in the office can have a negative effect on the productivity of employees (Lan et al., 2009; Niemela et al., 2002). This seems especially true for long tasks (> 60 minutes) often performed by knowledge workers. Dorgan and Dorgan (2005) state that if the Indoor Air Quality (IAQ) is not at the right level, this will have an impact on the occupant's health and productivity. Other factors affect the valuation of the indoor climate as well, such as the local climate, social and cultural habits (e.g. regarding clothing) (Kurvers and Leijten, 2013) and organisational factors like managing expectations, explaining and visualising the use of the installation and responding adequately to complaints (Pols, Karels and Ten Bolscher, 2009).

#### *Personal control*

Various researchers revealed that the ability to personally control environmental factors, like temperature, air quality, light and noise levels, has an impact on (self-reported) productivity (Leaman, 1995; Pols, Karels and Ten Bolscher, 2009; Boerstra, Loomans and Hensen, 2014).

Based on objective productivity measurements, Wyon (1996) concluded that the productivity effect of ideal personal control over the thermal environment is +2.7% for logical thinking, +7% for typing, +3.4% for skilled office work and +8.6% for repetitive office work. Boerstra, Loomans and Hensen (2014) found a 6%-10% higher perceived productivity when full personal control is experienced, compared to no control at all. Leaman and Bordass (1999) claimed that in seven out of 11 buildings a significant association was found between self-assessed productivity and perceived control. The lack of environmental control showed to be the most important concern for office occupiers. This finding is supported by Whitley, Makin and Dickson (1996) who found that people like to have an internal “*locus of control*” and say to be more productive when they perceive to have control over their physical environment.

#### *Light (daylight, windows, lighting)*

Galasiu and Veitch (2006) reviewed over 60 research studies on daylight in office environments and concluded that people strongly prefer daylight in workplaces. In general, larger windows are favoured. Fully automated systems receive low occupant acceptance. Individual control over lighting systems showed to be important to buildings users, and is especially appreciated if these systems are simple and easy to use. Preferred illuminance levels and discomfort glare in offices with daylight showed to be differently experienced by different persons.

#### *Greenery*

Various studies showed that the presence of greenery in the work environment can increase employee well-being, psychological comfort and productivity (Knight and Haslam, 2010; Smith and Pitt, 2009; Bakker and Van der Voordt, 2010). Plants have a number of measurable effects on the quality of the indoor environment by its influences on the light, temperature, relative humidity, air quality, noise, and static electricity. The reactions of people can be physical or physiological (e.g. blood pressure and headaches), affective (e.g. a positive mood), or cognitive (better concentration). Plants may have an indirect positive effect on productivity by its influence on health (Ulrich, 1984; Van den Berg, 2005) and behaviour (Wolf, 2002).

#### *Sound*

Among the most distracting sounds in the work environment are overheard conversations of others (Sundstrom et al., 1994). Not only noise from conversations, also the presence of (uncontrollable) background music seems to worsen performance compared to working in a silent environment (Furnham and Strbac, 2002). The layout is an important factor when it comes to distraction and the influence on productivity (see next sub-section).

### **Space**

#### *Communication and concentration*

Many studies have shown an impact of the office concept on (perceived) productivity (Hedge, 1982; Brill and Weideman, 2001; Haynes, 2008; De Been and Beijer, 2014). In a survey among 13.000 office employees working in different settings, Brill and Weideman (2001)

concluded that the two factors with the largest impact on performance and satisfaction are 1) the ability to work distraction-free and 2) the possibilities for interaction with co-workers (especially spontaneous interaction). This finding was confirmed by Haynes (2008) who states that interaction and distraction have the largest impact upon perceived productivity. In a Dutch survey study with over 7.000 respondents, similar results came to the fore: satisfaction with the possibilities to concentrate at work showed to be the most important predictor of the perceived individual productivity support, whereas satisfaction with communication possibilities was the most important predictor for the perceived support of team productivity (Maarleveld and De Been, 2011). The accomplishment of concentrated tasks as well as high quality teamwork are key elements in organizational performance (Hua et al., 2010). It is a challenge to create an environment which supports both activities.

### *Social interaction*

Spatial arrangements favouring spontaneous interaction (Brill and Weidemann, 2001) and collaboration (Strubler and York, 2007) are shown to be important to enable productivity. The large amount of visual accessibility in open work environments can facilitate effective communication among colleagues (Becker and Sims, 2000) and seems to lead to a higher frequency of interaction with co-workers (Bouttelier et al., 2008; Becker and Sims, 2000). Much interaction between colleagues occurs spontaneously (e.g. in a corridor, canteen or shared service area) (Backhouse and Drew, 1992; Hua et al., 2010). Appel-Meulenbroek (2014) showed that proximity, visibility and flow positively affect the number of interactions between knowledge workers and as such are supposed to stimulate innovation. Moments of communication seem to be more frequent but also shorter in open office environments compared to enclosed cell environments (Bouttelier et al., 2008; Becker and Sims, 2000).

The presence of dedicated meeting spaces does stimulate the amount of communication (Peponis et al., 2007; Oseland et al., 2011) and also the perceived support of collaboration, provided that these spaces are located close to the workstations (Hua et al., 2010). People prefer using meeting spaces which are conveniently located and which offer a certain level of privacy (Oseland et al., 2011).

There are indications that working in activity based office environments with various types of unassigned workplaces, and possibilities for remote working, even when including many places for communication, can also have a negative effect on communication, due to i.e. difficulties with finding each other and less social bonding (De Been, Beijer and Den Hollander, 2015).

### *Distraction*

However, working in an open setting often leads to distraction and disruption, resulting in lower support of perceived productivity compared to working in a cell office (Hedge, 1982; Brill and Weideman, 2001; Haynes, 2008; De Been and Beijer, 2014; Seddigh et al., 2014). The openness can lead to distraction particularly when conducting work which requires concentration (Hua et al., 2010) but also when doing creative work, since much creative thought takes place alone (Oseland et al., 2011). Open spaces, meeting spaces and



communication areas need to have good acoustic enclosure and should be strategically positioned in order to avoid distraction of employees working on nearby workstations (Hua, 2010; De Been, Beijer and Den Hollander, 2015).

#### *Task complexity and personal characteristics*

The activities performed by the buildings user and the accompanying task complexity seem to play an important role in the relationship between the environment and productivity. Whereas people working on complex tasks were found to be more satisfied and productive in a private office, those performing simple tasks appeared to perform better in a non-private setting (Block and Stokes, 1989; Haynes, 2008). Introverts seem to have even more difficulties with working on complex tasks while being distracted compared to extraverts (Furnham and Strbac, 2002).

### **Ergonomics**

The physical design of workstations and other office furniture has great importance for ergonomics, which can influence both health and productivity. For instance, a literature review by Karakolis and Callaghan (2014) showed that implementing sit-stand workstations in an office environment will likely result into lower levels of body discomfort and possibly also have a positive effect on performance. Research by Barber (2001) showed that, besides variables related to control, concentration and indoor climate, also other variables are considered important for productivity by office employees, such as ergonomic chairs, advanced technology (supporting IT facilities) and adequate (electronic) filing space. Ergonomics, enough space for items and access to technology are also mentioned as important influencing factors in the extensive research of Brill and Weidemann (2001).

Where office users use the same desk every day for their work activities then specific ergonomic considerations can be given to their desk and chair design. Therefore, an individual ergonomic solution can be designed for a particular office user (Sauter et al. 1991). However, the trend in today's modern office environment is more towards group interactions with collaborations being undertaken at multi-user workstations. Given that these multi-user workstations may be used by a number of different people throughout a working day then considerations need to be given to an ergonomic design that provides an optimal fit for a range of users (Mahoney et al. 2015).

We refer to the chapter on health and safety for further information on ergonomics.

### **Aesthetics**

Aesthetics are influenced by the architectural design of the exterior and the interior. Colour is one of the factors that affect well-being and mood (Mahnke, 1996; Kaya and Epps, 2004; Bakker, 2014), and people's behaviour (Elliot and Maier, 2007) and as such may also affect people's productivity (Bakker, 2014). Research has shown that the colour blue can enhance performance on creative tasks whereas red improves performance on detail-oriented tasks (Mehta and Zhu, 2009). However, an real life experiment, conducted by Bakker et al. (2013), showed no significant effect of a red, blue or neutrally coloured meeting room on the perceived outcomes of the meeting, the social cohesion of the group and wellbeing. Quite a large number of participants responded that colour of the meeting space had no effect on

productivity (65% of participants), collaboration (58%) and wellbeing (33%). Previously research has linked occupant comfort to indoor environmental quality (Huang et al. 2012, Frontczak and Wargocki 2011), whereas the Barrett et al (2013) research links these variables to student performance. In addition, they also add to the debate by identifying the aesthetic variable colour as impacting on students' performance (Barrett et al. 2013).

## KEY PERFORMANCE INDICATORS

Whereas many environmental aspects may have an impact on (perceived) productivity, it seems most important to users of an office building that the facility supports their current activities. A short list of activities is created based on what people consider most significant for their productivity: 1) support of concentration and 2) support of communication (table 1). The activities identified in table 1 could be subdivided into a number of other sub level activities. By also measuring the extent to which the work environment is perceived as supportive for the individual and team productivity, connections can be made with the support of the different activities. As such, the impact of the environment on the overall productivity can be evaluated.

Table 1: Proposed shortlist of KPIs

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The extent to which the work environment and facilities support the following activities (scores on a 5-point scale ranging from 1 – very unsupportive, to 5 – very supportive):

- Focused concentrated work
- Knowledge sharing
- Social interaction
- Your individual productivity
- Your team productivity

This list could be extended with questions regarding the perceived productivity support by important environmental factors such as the indoor climate, personal control, ergonomics, IT facilities and interior design,.

If possible, the subjective measurement of productivity should be completed with objective measures, e.g.:

- The actual output per employee (related to the sector and organisation, e.g. the number of students getting a diploma within the regular study period, or the number of transactions in a call centre)
  - The percentage of sick leave
  - Quality of the output (e.g. client satisfaction about the delivered output)
-

## How to manage productivity support

Table 2 shows a number of typical interventions that FM/CREM can implement to increase labour productivity. It also shows that it is not easy to create the best possible outcome because the benefits of various interventions and design choices are counterbalanced by negative impacts and risks.

Table 2: Interventions, management, benefits and sacrifices.

<b>Interventions</b>	<b>Management</b>	<b>Benefits</b>	<b>Sacrifices</b>
Create a more open work environment	Make the office more transparent, e.g. by using transparent materials, breaking down (some) current walls, etc.	Support of social interaction and collaboration.	Cost of project. Risk: less privacy, more distraction.
Create places to enable concentration	Create enclosed concentration cells or silent concentration zones and/or carry out acoustic measures, especially when the work environment is (relatively) open.	Increase of concentration opportunities.	Cost of planning and re-designing the work environment. Risk: too much enclosure which can possibly lead to less knowledge sharing.
Create an optimal indoor climate	Take care of a climate installation that results in a comfortable temperature, sufficient ventilation. Pay attention to lighting and comfortable acoustics.	Increase of employee satisfaction. Improved health and well-being.	Cost of extra facilities.
Give people more personal control about their environment	Give employees (more) freedom in where, when and how to work. Create opportunities to personalise the environment. Create opportunities to personally control the indoor climate.	Increased employee satisfaction and commitment. Improved health and well-being.	Managers should manage their employees in a different way (results-oriented). Personalisation may lead to appropriation of personal desks. Individual control of indoor climate may lead to conflicts between employees.
Provide ergonomic furniture	Replace non-ergonomic furniture by ergonomic, adjustable chairs and tables.	Improved health and well-being, less risks of fatigue or illness.	Cost of ergonomic furniture.
Provide supporting IT facilities and an (electronic) filing system	Provide IT facilities and filing system that suits work processes and (expected) flexibility of employees.	Support of work processes in general. Essential prerequisite of flexible working.	Cost of facilities.

## PERSPECTIVES

Although much research has been conducted into the impact of buildings and facilities on labour productivity, still much work has to be done, in particular regarding:

- The differentiation in understand individual needs and preferences of different groups, classified e.g. by gender, age, psychological and profile..
- Productivity outcomes per work type, e.g. classified by job title, type of work and flexibility of the work.
- Defining a typology of work environments. Clear definitions need to be made with regards to the different spaces so that research findings can be made more meaningful when extrapolated to a wider context.
- Operationalisation of input and output factors, preferably in a quantitative way.
- Interpretation and explanation of cause-effect relationships and the impact of intermediary variables, for instance by in-depth interviews, focus groups and expert meetings.
- Statistical analysis of quantitative data in search of correlations and weights of the relative contributions of different input variables on (perceived) productivity.
- A combination of cross-sectional and longitudinal studies. The cross-sectional studies allow for comparisons across a number of buildings at a certain instant in time, whereas the longitudinal studies allow for pre-evaluation, an intervention and post-evaluation.
- Cross-case analyses of different settings (offices, educational facilities, retail and leisure, health care) using standardised research methods..

## References

- Aronoff, S. and Kaplan, A. (1995) *Total Workplace Performance: Rethinking the Office Environment*, WDL Publications, Ottawa, Canada, 1995.
- Appel-Meulenbroek, R. (2014) *How to measure added value of corporate real estate and building design. Knowledge sharing in research building*, PhD thesis TU Eindhoven.
- Backhouse A. and Drew, A. (1992) 'The design implications of social-interaction in a workplace setting', *Environment and Planning B: Planning and design*, 19(5), 573-584.
- Bakker, I. (2014) *Uncovering the secrets of a productive work environment. A journey through the impact of plants and colour*, PhD Thesis, Faculty of Industrial design, TU Delft.
- Bakker, I., Van der Voordt, Th., Vink, P. and De Boon, J. (2013) 'Red or Blue meeting rooms: does it matter? The impact of colour on perceived productivity, social cohesion and wellbeing', *Facilities*, 31(1/2), 68-83.
- Bakker, I., and Van der Voordt, D.J.M. (2010) 'The influence of plants on productivity. A critical assessment of research findings and test methods', *Facilities*, 28(9/10), 416-439.
- Barber, C. (2001), The 21st-Century Workplace, In: Kaczmarczyk et al, *People and the Workplace*, GSA Office of Governmentwide Policy, Washington DC.
- Barret, P., Zhang, Y., Moffat, J. and Kobbacy, K. (2013). 'A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning'. *Building and Environment*, 59(0), pp. 678-689.
- Batenburg, R. and Van der Voordt, D.J.M. (2008) 'Do Facilities Matter? Effects of Facility Satisfaction on Perceived productivity', *Proceedings of the European Facility Management Conference*, Manchester, 10-11 June 2008, 139-150.

- Becker, F. and Sims, W. (2000) *Offices That Work: Balancing Cost, Flexibility, and Communication*. New York: Cornell University International Workplace Studies Program (IWSP).
- Boerstra, A. C., Loomans, M. G. L. C. and Hensen, J. L. M. (2014) 'Personal control over indoor climate and productivity', *Proceedings of Indoor Air 2014*, 7-12 July 2014, Hongkon, China (pp. 1-8). Hongkong.
- Block, L. K. and Stokes, G. S. (1989) 'Performance and satisfaction in private versus non-private work settings', *Environment and Behavior*, 21, 277 – 297.
- Blok, M., Groenesteijn, L., van den Berg, C., and Vink, P. (2011) 'New ways of working: A proposed framework and literature review', In: M. M. Robertson (Ed.), *Ergonomics and health aspects* (pp. 3-12), Heidelberg: Springer-Verlag. HCII 2011, LNCS 6779.
- Bouttelier, R., Ullman, F., Schreiber, J. and Nael, R. (2008) 'Impact of office layout on communication in a science-driven business', *R&D Management*, 38(4), 372-391.
- Brill, M., and Weidemann, S. (2001) *Disproving widespread myths about workplace Design*. Jasper, IN: Kimball International.
- Christopher, W. F. and Thor, C. G. (eds.) (1993) *Handbook for Productivity Measurement and Implementation*. Portland: Productivity Press.
- Clements- Croome, D. (2000) *Creating the Productive Workplace*. New York, USA: Taylor & Francis.
- Davenport, T. H. and Prusak, L. (2000) *Working knowledge*. Boston, MA: Harvard Business School Press.
- De Been, I. , and Beijer, M. (2014) 'The influence of office type on satisfaction and perceived productivity support', *Journal of Facilities Management*, 12(2), 142-157.
- De Been, I., Beijer, M. and Den Hollander, D. (2015) 'How to cope with dilemmas in activity based work environments: results from user-centred research', *European Facility Management Conference EFMC 2015*, Glasgow, 2-3 June 2015.
- Dorgan, C. E. and Dorgan, C. B.( 2005) 'Assessment of link between productivity and indoor air quality', in *Creating The Productive Workplace*, D. Clements-Croome, 2nd ed., E and FN Spon, London, pp. 113-135.
- Elliot, A. and Maier, M.A. (2007) 'Colour and psychological functioning', *Current Direction in Psychological Science*, 16(5), 250-254.
- Frankema, E. H. P. (2003) *Kantoorinnovatie in economisch perspectief*. Delft: Center for People and Buildings.
- Frontczak, M. and Wargocki, P. (2011)' Literature survey on how different factors influence human comfort in indoor environments'. *Building and Environment*, 46(4), pp. 922-937.
- Furnham, A. and Strbac, L. (2002) 'Music is as distracting as noise: the differential distraction of background music and noise on the cognitive test performance of introverts and extraverts', *Ergonomics*, 45(3), 203-217.
- Galasiu, A. D. and Veitch, J. A. (2006) 'Occupant preferences and satisfaction with the luminous environment and control systems in daylight offices: a literature review', *Energy and Buildings*, 38, 728-742.
- Greene, C. and Myerson , J. (2011). 'Space for thought: designing for knowledge workers' *Facilities*, 29(1), pp. 19-30.
- Halkos, G. and Bousinakis, 2010 'The effect of stress and

- satisfaction on productivity', *International Journal of Productivity and Performance Management*, 59(5), 415-431.
- Hanssen, S. O. (2000) *Economics vs. Indoor Climate - a Basis for Deciding Appropriate Measures and Rational Decision Models in Building Administration*. Oslo: Research Council of Norway.
- Haynes, B.P. (2007) 'An evaluation of office productivity measurement', *Journal of Corporate Real Estate*, 9(3), 144-155.
- Haynes, B. P. (2008) 'Impact of workplace connectivity on office productivity', *Journal of Corporate Real Estate*, 10(4), 286 – 302.
- Haynes, B. P. (2012) 'Conversational Networks in Knowledge Offices' In: K. Alexander and I. Price, eds, *Managing Organizational Ecologies: Space, Management and Organization*. Routledge New York, NY, pp. 201-212.
- Hedge, A. (1982) 'The open-plan office. A systematic investigation of employee reaction to their work environment', *Environment and Behavior*, 14, 519-542.
- Hua, Y., Loftness, V., Kraut, R. and Powell, K. M. (2010) 'Workplace collaborative space layout typology and occupant perception of collaboration environment', *Environment and Planning B: Planning and Design*, 37, 429-448.
- Huang, L., Zhu, Y., Ouang, Q. and Cao, B ( 2012) 'A study on the effects of thermal, luminous, and acoustic environments on indoor environmental comfort in offices. *Building and Environment*, 49, pp. 304-309.
- Karakolis, T. and Callaghan, J. P. (2014) 'The impact of sit-stand office workstations on worker discomfort and productivity: A review', *Applied Ergonomics*, 45, 799-806.
- Kaya, N. and Epps, H.H. (2004) 'Relationship between colour and emotion, a study of college students', *College Student Journal*, 38, 396-405.
- Kaczmarczyk, S. et al. (2001), *People and the Workplace*. GSA Office of Governmentwide Policy, Washington DC.
- Keizer, J. and Van Eijnatten, F. (2000) *Improving productivity via workspace design. An exploratory study*. Department of Technology Management, TU Eindhoven (TU/e).
- Kleeman, W. B., Duffy, F., Williams, K. P. and Williams, M. K. (1991) *Interior design of the electronic office: The comfort and productivity payoff*. New York: Van Nostrand Reinhold.
- Knight, C. and Haslam, S. A. (2010) 'The relative merits of lean, enriched, and empowered offices: An experimental examination of the impact of workspace management strategies on well-being and productivity', *Journal of Experimental Psychology: Applied*, 16(2), 158-172.
- Kurvers, S. R. and Leijten, J. L. (2013) 'Thermisch comfort: huidige en toekomstige normen', *TVVL Magazine*, 06/2013, 46-51.
- Lan, L., Lian, Z., Pan, L. and Ye., Q. (2009) 'Neurobehavioral approach for evaluation of office workers' productivity: The effects of room temperature', *Building and Environment*, 44, 1578 – 1588.
- Leaman, A. (1995) 'Dissatisfaction and office productivity', *Facilities*, 13(2), 13 – 19.
- Leaman, A. and Bordass, B. (1997) 'Productivity in Buildings: the 'killer' variables'. Paper presented at the *Workplace Forum*, London, October 1997.
- Leaman, A. and Bordass, B., 1999. Productivity in buildings: the 'killer' variables. *Building Research & Information*, 27(1), pp. 4-19.

- Maarleveld, M. and De Been, I. (2011) 'The influence of the workplace on perceived productivity', *European Facility Management Conference*, Conference Paper, May 2011.
- Maarleveld, M., Volker, L. and Van der Voordt, T.J.M. (2009) 'Measuring employee satisfaction in new offices – the WODI toolkit', *Journal of Facilities Management*, 7(3), 181-197.
- Mahnke, F. (1996) *Color, Environment, Human Response*. New York: Van Nostrand Reinhold.
- Mahoney, J.M., Kurczewski, N.A. and Froede, E.W., 2015. Design method for multi-user workstations utilizing anthropometry and preference data. *Applied Ergonomics*, **46**, Part A(0), pp. 60-66.
- Mawson, A. (2002), *The Workplace and its Impact on Productivity*, London: Advanced Workplace Associates Ltd.
- Mehta, R. and Zhu, R.J. (2009), 'Blue or Red? Exploring the Effect of Colour on Cognitive Task Performance', *Science Express*, 3223(5918), 1226-1229.
- Niemelä, R., Hannula, M., Rautio, S., Reijula, K. and Railio, J. (2002) 'The effect of air temperature on labour productivity in call centres – a case study', *Energy and Buildings*, 34, 759 – 764.
- Oseland, N., Marmot, A., Swaffer, F. and Ceneda, S. (2011) 'Environments for successful interaction', *Facilities*, 29(1/2), 50 – 62.
- Oseland, N. (1999) *Environmental Factors Affecting Office Worker Performance: A Review of Evidence*. London: Chartered Institution of Building Services Engineers : DETR.
- Peponis, J., Bafna, S., Bajaj, R., Bromberg, J., Congdon, C. and Rashid, M. (2007) 'Designing space to support knowledge work', *Environment and Behavior*, 39( 6), 815-840.
- Pols, J. P., Karels, M. and Ten Bolscher, G. H., (2009) 'Praktijkonderzoek in tien energiezuinige gebouwen. Gezond binnenklimaat niet vanzelfsprekend', *VV+*, november 2009, 642 – 649.
- Sauter, S.L., Schleifer, L.M. and Knutson, S.J. (1991) 'Work Posture, Workstation Design, and Musculoskeletal Discomfort in a VDT Data Entry Task'. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, **33**(2), pp. 151-167.
- Seddigh, A., Berntson, E., Bodin Danielson, C. and Westerlund, H. (2014) 'Concentration requirements modify the effect of office type on indicators of health and performance', *Journal of Environmental Psychology*, 38, 167 – 174.
- Smith, A. and Pitt, M. (2009) 'Sustainable workplaces: improving staff health and wellbeing using plants', *Journal of Corporate Real Estate*, 11(1), 52-63.
- Strubler, D. C., and York, K. M. (2007) 'An exploratory study of the Team Characteristics Model using organizational teams', *Small Group Research*, 38(6), 670-695.
- Sullivan, J., Baird, G. and Donn, M. (2013) *Measuring productivity in the office workplace. Final report*. Centre for Building Performance Research, Victoria University of Wellington, Wellington, New Zealand.
- Sundstrom, E., Town, J.P., Rice, R.W., Osborn, D.P. and Brill, M. (1994) 'Office noise, satisfaction, and performance', *Environment and Behavior*, 26, 195-222.
- Ulrich, R.S. (1984) 'View through a window may influence recovery from surgery', *Science*, 224, 420-1.

- Van den Berg, A.E. (2005) *Health impacts of healing environments: A review of the benefits of nature, daylight, fresh air and quiet in healthcare settings*. Groningen: Foundation 200 years University Hospital Groningen.
- Van der Voordt, D.J.M. (2003) *Costs and benefits of innovative workplace design*. Delft: Center for People and Buildings.
- Von Felten, D., Böhm, M. and Coenen, C. (2015) 'Multiplier Effects through FM services: A survey-based analysis of added value in FM', *European Facility Management Conference EFMC 2015*, Glasgow, 2-3 June 2015.
- Vos, P.G.J.C. and Dewulf, G.P.R.M. (1999) *Searching for data: a method to evaluate the effects of working in an innovative office*. Delft: Delft University Press.
- Whitley, T. D. R., Makin, P. J., and Dickson, D. J. (1996) 'Job satisfaction and locus of control: Impact on Sick Building Syndrome and self - reported productivity', *7th International Conference on Indoor Air Quality and Climate*, Nagoya, Japan.
- Wolf, K.L. (2002), The impact of nature in and around shop areas; creation of an environment specifically suited to a consumer. Paper presented at the *People/Plant Symposium*, Amsterdam.
- Wyon, D. P. (1996) 'Individual microclimate control: required range, probable benefits and current feasibility', *Proceedings of the 7th International Conference on Indoor Air Quality and Climate*. Vol. 1, 1067-1072.