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Smart and Sustainable Offices (SSO): Showcasing a holistic approach to realise the next generation offices

Smart and Sustainable Offices (SSO): Presentación de un enfoque holístico para implementar la próxima generación de oficinas

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ABSTRACT

The Smart Sustainable Offices project (SSO) is a product of years of research with large sets of data collected from more than 30 office buildings in Switzerland, Sweden, and Spain. Based on scientific evidence, the concept of SSO, initially conceived as a research plan to address the interdependencies between office users and their working environment in a European context, is now used as a qualitative and quantitative mixed method approach for office diagnosis and ideation. At the current stage, the SSO methodology aims to implement a new paradigm of user-oriented, lower carbon footprint and resilient office design solutions. The main strategy is articulated around the "office DNA" of every organisation, decoded as a compound of work patterns, operational and individual needs, and their potential to define design criteria. The practical application of SSO and its tentative findings exemplified through three pilot test office-demonstrators are described in this paper.

Keywords: Office DNA; employees' needs; comfort experience; indoor environmental quality; sustainable office design; space-resilience; work patterns.

RESUMEN

El proyecto Smart Sustainable Offices (SSO) es un producto de años de investigación y cientos de miles de datos recogidos en más de 30 edificios de oficinas de Suiza, Suecia y España. Inicialmente concebido para investigar las interdependencias entre usuarios de oficinas y su entorno de trabajo en un contexto europeo, ha terminado convertido en un modelo mixto cualitativo y cuantitativo para el diagnóstico e ideación de oficinas, apoyado en evidencias científicas. Actualmente, la metodología SSO pretende implementar un nuevo paradigma de oficinas orientadas al usuario, con menor huella ambiental y espacios resilientes. La estrategia principal se articula alrededor del «ADN de la oficina» de cada organización, descodificado como un compuesto de patrones de trabajo, necesidades operativas e individuales, junto a su potencial para definir criterios de diseño. La práctica de SSO y los resultados provisionales de estudios piloto en tres oficinas demostrativas son descritos en este artículo.

Palabras clave: *ADN de la oficina, necesidades de los empleados, experiencia de confort, calidad ambiental interior, diseño sostenible de oficina, resiliencia del espacio, patrones de trabajo.*

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1. INTRODUCTION

The fractured nature of stakeholders in building sector impedes needed changes, and new approaches are to keep up with the societal needs for equitable and smart buildings that fit users' demands, wishes and behaviour. Equally critical is the need for a reduction in environmental impacts, where buildings play a key role by contributing to climate change with 40% on a European average. The still increasing amount of building certification systems, e.g. BREEAM, LEED, DGNB, and Minergie, portrays that we are on a path leading to energy efficiency and low carbon buildings. However, a relatively few number of buildings are currently certified compared to the total number of newly built buildings (1). Within the construction sector, the rate of cooperation, expansion in the diversity of goods, incorporation of external knowledge, as well as market expenditure are low compared to those of other industries (2).

A strong focus on investment costs in the office design and energy efficiency measures are considered expensive with a low return on investment. From the economic perspective, the contribution of the users and their needs and potential are often neglected. Thus, future resilient workspaces need to take users' needs into account and be adaptable to the dynamic changes in today's work environment (office organisation and design) as well as increasing demands on the Indoor Environmental Quality (IEQ). Today, such a holistic approach towards design that encompasses the connections between the different elements is missing. To achieve this, an investigation of the relationships between efficient building operation that embraces office building performance and its usability under a fit-to-the-human needs perspective is imperative. Thus, these relationships bring to the fore aspects like perceived comfort vs. measured IEQ, levels of stimulation, well-being and support provided by the built environment, and the cumulative effect on factors such as productivity, satisfaction, or energy consumption.

Given that office spaces only acquire meaning and purpose when used, the "office DNA", meaning the conjugation of work patterns, operational, and individual needs, provides organisation-specific key information for determining characteristics like office composition, architectural qualities, workstation settings, lifestyle references, office dynamics, and equipment. External factors such as geographical location, climate conditions, or surrounding buildings also influence construction designs, whereas a unique identity and organisational culture are to be revealed in the office design as a finishing layer. Accordingly, it could be reasonable to claim that holistically optimised offices lead to lower lifecycle costs, effective gains, and enhanced community support.

Indeed, arguments for more sustainable and greener office buildings via side or co-benefits such as well-being and health, adding to the energy saving effects is not considered new. Many previous studies have shown that improving health and wellbeing conditions at work may result in productivity gains (3) (4). In the last years, researchers in work psychology have focused on studying the different aspects that may ensure high levels of wellbeing and work performance and establishing the fact that work context, i.e. the built environment, has an impact on employees' health (5). In fact, employees satisfied with the overall environmental quality of their workspace have been reported to be more productive (6), what manifests itself in a lower rate of employees' absenteeism and a higher organizational resilience. Moreover, international standards (7) (8) as well as building certification schemes, emphasised the crucial role of IEQ to ensuring that human health and wellbeing are well integrated into future office buildings.

These co-benefits are surfacing as a solution or potentials to also convince those stakeholders that have been discouraged by the short-term economic incentive that lower initial investments represent relative to the long-term profitability of a higher investment rate (9). However, even with a lifecycle perspective, there are limited economic arguments to surpass the regulations of energetic standards and targets of more energy efficient building. This could be attributed to low average energy prices, in addition, to a very limited consideration of carbon emissions in cost calculations. For example, discounted cash flow analysis (DCF) and non-calculation on the impact of wellbeing during a building's use-phase and its office users' behaviour (10).

Although about 90 % of typical operating costs in office buildings are linked to staff costs, property/rental derived costs is commonly seen as the largest potential for cost savings. Hence, it is considered the second highest companies' operational cost (11). As one of the consequences, desks clustering in open-plan office designs has been widely adopted and replicated as the solution that densifies occupancy (12). This approach often pays less attention to organisational cultural particularities, i.e. specific working patterns, etc. Without any statistical validity (of data) that backs such a transformation approach, it is likely that a space-efficient office design will negatively affect comfort, well-being, and productivity at work or, worst, increase environmental related stress (13).

The Smart Sustainable Offices project (SSO) deals with the relationship between the quality of office buildings, i.e. the built environment and the way in which employees interact with the working environment. Supported by the Climate-KIC and co-led by Chalmers University of Technology (Sweden) and Valencia Institute of Buildings (Spain), the SSO has seen a continuous growth in the European context. The SSO builds on a large baseline study that consists of more than 6000 questionnaires and 200.000 measurement points for IEQ that have been collected from a sample of 27 office buildings in Switzerland over a period of two years. Notwithstanding, the SSO's is also targeting the Nordic and Mediterranean climate contexts for potential growth. The SSO approach, introduced below, aims to pioneer a diagnosis and strategy implementation for a new generation of user-oriented, lower carbon footprint, and resilient office design solutions, to provide empirical evidence for future offices. This paper follows the pathway of SSO by introducing the SSO methodology, description of the practical application in a three pilot test office-demonstrators, and reports on its provisional findings. Furthermore, the experiences and lessons learnt are explained and, finally, an outlook into the future is presented.

2. FRAME OF REFERENCES

The current research is built on the premise that if we can understand the ways in which office employees interpret and use their workspaces in their daily routines, we will be better positioned to plan and execute valuable interventions that equally support the sustainable growth of people and organisations. In this regard, diverse interpretations from numer-

ous fields can be found in literature, where the SSO approach is positioned around three points: user's needs as a core strategy, energy as a boundary condition, and spatial resilience as the mechanism to cope with changing needs from a holistic perspective.

2.1. User-oriented office design

Demand-driven design and organisation of the working environment have been well researched with diverse results. Different office typologies have been the subject of various studies on its impact on employees' health status and productivity (14) (15), wellbeing (16), satisfaction (17) (18), performance (19), behaviour (20), etc. Notwithstanding the rich literature, misleading and contradicting inferences could result when only selective (few) effects are considered in a study.

Contemporary office design is progressively embracing the concept of Activity-Based Offices (21) (22) as a way to offer diverse office setting for the tasks in progress at each moment, while workstations are shared to get more out of limited resources. However, this theoretically coherent idea easily risks entailing disadvantageous scenarios, if it is primarily executed on partial criteria such as the potential for economic gains. Decreasing the office surface and the number of workstations without taking the users' needs into account is likely occur at the expense of the workforce and productivity (23).

Nevertheless, the spatial reduction is just one of the numerous issues that office users have to face nowadays. Archetypal open spaces expose people to extra cognitive loads due to noise and visual distractions (24) or a recurrent lack of privacy (25). The incapacity to control the environment together with increasing demands for multitasking, amplify the vulnerability to disturbances from irrelevant office stimuli (26).

Likewise, behavioural patterns can be a source of conflicts and incompatibilities if there are no defined spaces, rules or clues, and thus a relevant factor to be considered (27). People´s ability to block out distractions is found to be connected to their performance at clustered workspaces, where individual differences suggest that the exposure to many inputs can overload the senses in many cases, requiring extra efforts to achieve given results (28). Even at non-territorial offices, employees are often exposed to tough trade-offs; the proximity to a work unit, the opportunities to socialise and/or the personalisation and tenure of a preferred location within the office which are ultimately prioritised over the drawbacks of remaining at the same place (29). Additionally, the freedom to choose a place that better fits to employees' indoor climate preferences, is found to correlate with higher levels of satisfaction for workers with a moderately heterogeneous activity profile (30).

Notwithstanding, IEQ conditions are identified as key influential factors on employees´ health, satisfaction, and productivity (31). Moreover, in environments like cell-offices, employees usually report superior comfort experience because they have higher control on IEQ parameters. On the contrary, social aspects of design, collaboration and peer affinity score are relatively lower in cell-offices compared to other office types (32).

All the above inferences aligned well with studies which couple office design and performance over time to feelings of pleasure linked to the daily work due to improved work engagement, job satisfaction and well-being in the office (11) (33). Thus, implementations of multiple design-related variables as standardised office models may well have positive and harmful effects on office workers and organisations. Accordingly, an accurate validation and holistic solutions to fit individual needs are required.

2.2. Energy efficiency and renewables

After several years of debates that energy efficiency technology can pay for itself via the achieved energy savings, it is obvious that this incentive is not sufficient for a massive scale change (see above). Buildings are still responsible for approximately 40 % of the primary energy consumption in Europe, which is often considered as the largest energy consumer and CO2 emitting source in cities (34). It is estimated that the average energy consumption in non-residential sectors in Europe is 280kWh/m2 (covering all end-uses). In addition, offices have a share of 26 % of the total energy use, 23 % of total floor area of non-residential buildings and the specific average energy consumption account for about 316 kWh/m2, for a European building stock that comprises roughly 1.3 billion m2 of useful office floor space and about 1.2 million employees working in different offices (35). Obviously the energy consumption for conditioned floor spaces, will strongly depend on building location, construction, HVAC (heating, ventilation and air-conditioning) systems, lighting installations, type of office equipment and its use, operating schedules, etc. The main GHG source in office buildings is the energy use of the building during its operational phase (36). Additionally, the level of the so-called embodied or grey energy, also considered in life cycle assessments of buildings today, equates to the average of operational energy over a building's lifetime of 80 years (37).

Furthermore, for a typical single-occupancy office room, an austere workstyle consumes up to 50 % less energy, while a wasteful workstyle consumes up to 90 % more energy, compared to the standard or reference workstyle (38). Nonetheless, a higher energy use is not directly related to improved well-being (39). Thus, there is a significant potential to mitigate carbon emissions that currently stood at about 11 Gt CO2-eq. (40) considering an average CO2-emission factor of 0.4 kg CO2-eq./kWh (41). Assuming a positive influence of 10 % on the office user behaviour towards the positive aspect (austerity workstyle), ca. 110 kt CO2-eq. could be saved per year.

On the other hand, studies have found that the so-called "green buildings", especially when certified, are often less energy efficient than expected when their measured energy consumption during the phase of operation is compared to the expected energy demand that has been estimated in the early design stage (42). Among the hypothesis in this context, the user behaviour is considered as a central player.

Besides the energy efficiency goals, a larger utilisation of renewable energies is encouraged by the European Commission and many national regulations in such manners that will transform the offices of the future. Article 4 of the EPBD recast requires Member States to set and ensure minimum energy performance requirements which: "shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, as well as local climatic and surrounding environment conditions and the designated function and the age of the building" (43) (44).

Photovoltaic (PV) modules integrated into the facades, in addition to modules on the roofs, will become standard since their prices are on the decline. The consideration of double-functions in building elements, such as energy generation and shading, facade and energy production etc. becomes a crucial element of the future architectural design approaches.

2.3. Space resilience and office DNA

The term office DNA applied to office spaces under the SSO perspective, describes a new component in the design process wherein work patterns, organisational and individual needs are identified and matched with the design criteria of the office physical characteristics. Furthermore, different job-related characteristics such as the levels of interaction with co-workers, task complexity, variability, content or degree of formality outline diverse work patterns. Although the work patterns require variable design parameters for space planning, layouts and workstation settings are designed without having a coherent understanding of users' activities, which subsequently results in conflicts (45). According to Haynes (46), "any theoretical framework for office productivity must consist of both the physical environment and the behavioural environment, and in addition, must accommodate the different work patterns that office occupiers can adopt".

SSO has identified several differentiated work patterns categories that demand specific design criteria in terms of space, layout landscape, acoustic and lighting settings, indoor climate conditions, etc. For example, an employee working independently in a high cognitive-demanding task, requires higher environmental seclusion, less exposure to interaction, individualised access to media, and other resources to enable a suitable level of concentration. Contrarily, professionals in a co-creative workshop need to be provided with higher stimulation, freedom of movement and interaction, ease of access, shared media, flexible settings, etc. Both cases use the space in diametrically opposed manners, which also makes incompatible their physical proximity. Nonetheless, those needs can evolve over time towards redistributed work patterns and additional hires or renewed organisational goals within the same office. Therefore, the term resilience in SSO project refers to the capacity of facilities to deal with the changes and continuous development of the organisations that occupy them. A resilient office space should be built to support the current and future office DNA of the organization, foster a maximum flexibility, and a proper balance between consistency of results and investments in the long term.

In this respect, a coherent interior design scheme oriented to custom-built "spatial modules" would effectively accommodate the full range of activities that employees must perform at work and simultaneously yield solutions that are scalable, adaptable, replaceable, compatible, reliable, etc. The existing interdependencies between users, work patterns, environmental conditions, and spatial contents, remark the significance of approaching the working experience at offices as a dynamic system of activities where the people usually spend a great part of the day.

3. RESEARCH APPROACH AND METHODOLOGY

Figure 1 clarifies the underlying philosophy of the science-based SSO model for office planning, construction, and operation of new buildings as well as existing ones to be reorganised or renovated. Traditionally, the office design process is linear and follows a design/architectural briefing that outlines what the office space might look like, following requirements of the organisation´s head-office and/or building owners. In the case of a new construction, this is often even more disconnected from the real employees' needs, where tenants are unknown and spaces become generic, thus charging the user with the responsibility to adapt to a workplace and not vice versa.

Conversely, the SSO always starts with a pre-intervention study to identify the user´s needs and work patterns as the core of any organisations. This is done by applying a mixed-method approach, consisting of a set of tools for qualitative and quantitative data gathering and analysis such as surveys, observation sessions, interviews, workshops, and physical measurements. The referred data is analysed to shape the picture of the organisation and its specific office DNA through the identification of operative needs, user perceptions and routines, different parameters of satisfaction, well-being and productivity, as well as objective considerations of the IEQs and office dynamics. Based on a comprehensive analysis, recommendations are filed for either architecture of the building and/or building technology and/or office organisation and/or interior design. Furthermore, the innovative added value is provided by deep insight studies that drive – on each level – an advanced and demand-oriented building design. Thus, based on the multi-method approach, office design or any type of intervention towards a new office design can be built like a bespoke suit for each customer, where employees and management are active parts of the ideation.

Nonetheless, the office DNA is dynamic and requires flexible solutions able to evolve alongside with the organisation over time. Therefore, post-intervention studies are also considered in the SSO evaluation and planning process. This may easily turn into cyclical assessments that are scheduled according to every particular situation. Therefore, the SSO model can be represented as a circular process that starts where the linear office design conventionally ends.

3.1. SSO study step by step

The different tools and measurements involved in each study, are chronologically organised in a protocol of seven stages (see figure 2) to be consistently implemented in the same order. This will make it easier to match the findings between case studies that contribute to a more consistent database and control the information for research issues at each stage to avoid early conjectures or biased responses.

The first step is to introduce the SSO project to the office employees in a meeting that should last about 30 minutes, with the objective of getting their engagement from the very first moment. The meeting session is to explain the overall goals and timeline for the study, address reservations and concerns with comprehensive information, elaborate on the confidential treatment of any data collected and highlight the key role of every individual in a future office environment. Since the method aims to provide relevant results based on significant data and co-creation, it is vital to seek for the highest possible rates of participation and management´s commitment.

Secondly, an advanced investigation of the building and workspace is done to prepare the study. This involves the

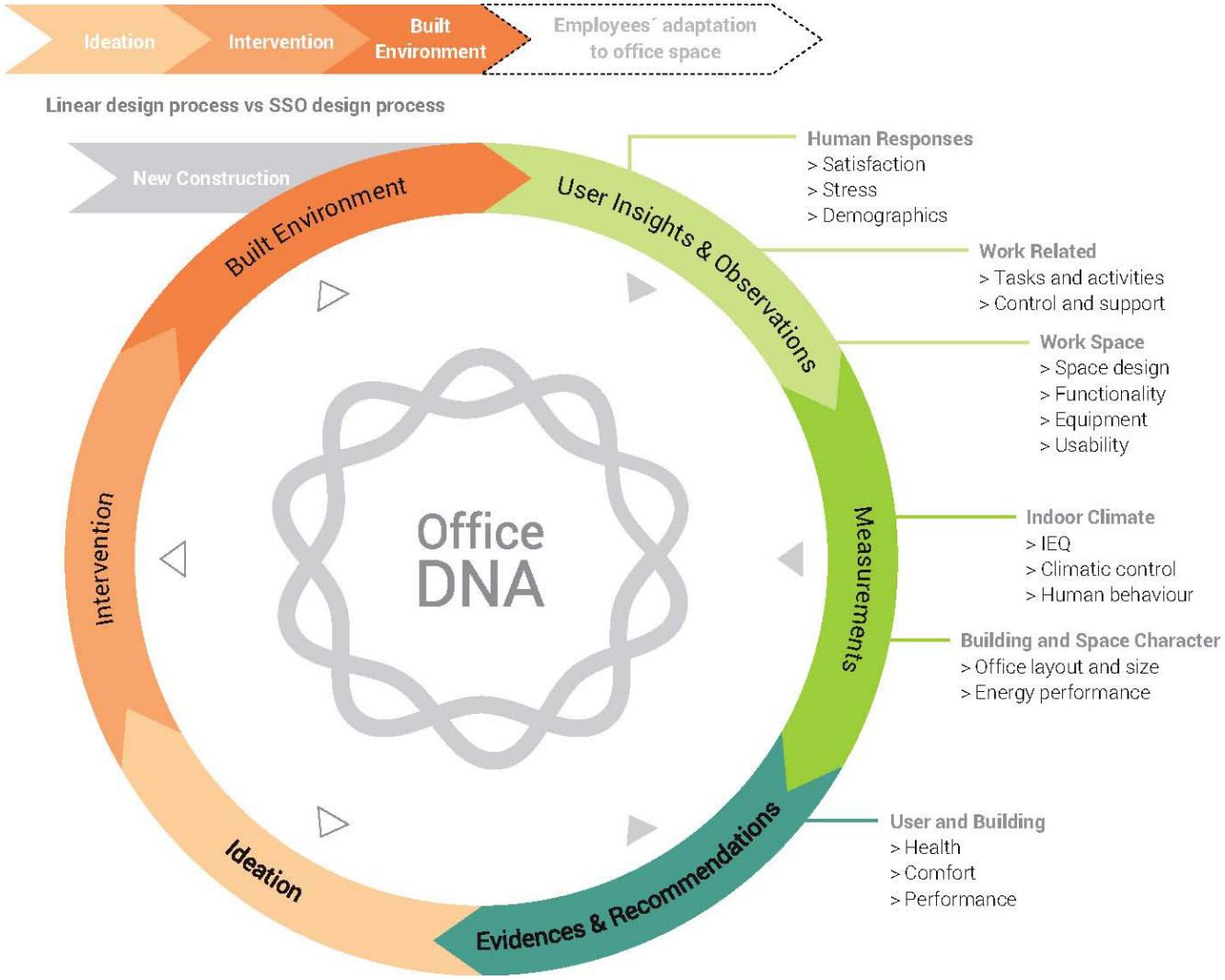

Figure 1. Linear Design Process vs circular SSO Design Process.

compilation of relevant building information like floor plans, orientation, HVAC system and ventilation outlets, spatial divisions, size and layout of working areas, type of windows, lighting arrangements, access to daylight and incidence of direct sunlight, and service zones (copy machines, coffee hall, etc.) to be able to model the building and create a measurement plan with dedicated instruments according to that information among other aspects.

Once the preparatory phase is ready, it is time to start collecting data from the employees through Diary, Questionnaire and IEQ measurement, running in parallel in the course of one week. Both Diary and Questionnaire, are two new assessment tools in a web-based format, initially drafted in close collaboration between the Swedish and Spanish SSO research team, who took the experience of the Swiss study as a reference (47), and later further developed, validated and professionalised it.

Diary is a short survey to analyse the change of certain variables over time. It consists of a 3-5 minutes session that must be completed twice a day from Monday to Friday; once before lunch and once before leaving the office. The variables studied are work patterns, health condition, mood, and perceived IEQ.

Questionnaire is a longer survey (20-30 minutes) that focuses holistically on preferences at work in general. The variables studied are job satisfaction, satisfaction with the working environment and facilities, life satisfaction, well-being, satisfaction and control possibility with IEQ, health condition, mood, equipment, self-assessed performance, comfort interventions, work patterns, support and feedback, energy-related behaviour, and demographics.

The IEQ measurements cover the whole study period. They consist of a continuous and spot registration of diverse parameters at different times and workspace locations, to detect indoor climatic problems and to compare the data obtained from other sources. The variables studied are air temperature, air velocity, relative humidity, carbon dioxide, illuminance level and glare, sound pressure level, speech privacy, as well as particulate matters and volatile organic compounds.

Ideally, these surveys and objective measurements should be carried out once in the summer and once in the winter to ensure an analysis independent from exceptional seasonal conditions.

The fourth stage comprises observations and interviews with office representatives carried out to probe further into rel-

Figure 2. Stages of SSO study.

evant questions and obtain extra qualitative information to describe critical issues. The extent of observations depends on the space syntax relating to the size of the space analysed and the number of relevant points to observe, given that each space should be covered several times a day and different days of the week.

The procedure mainly consists of defining a route across the office, choosing relevant points to observe at regular intervals and registering the activity that takes place.

Interviews depend on the subjects to be addressed and are to be planned to represent the office while considering the number of participants. In the case of large workforces, employees can be recruited for focus group interviews with up to 20 participants instead.

As soon as the office user insights have been collected and the analysis of the data produces the first preliminary results, the protocol enters the fifth phase characterised by co-creation sessions. After which, workshops are organised with groups of a maximum of 10 employees to discuss and evaluate a set of proposals for spatial interventions based on previous feedback. Each session takes up to two hours and the knowledge developed in common is used as a filter for preliminary hypotheses. The co-creation workshops also have the mission to actively involve the people by stimulating creative inputs, so their motivation and willingness to collaborate are constructively reinforced. The results from this stage together with the findings from the previous ones are combined and analysed, and summarised in final recommendations for intervention.

The next step is to transfer the outcomes to a report and a technical dossier to be presented at two levels: the report as a customer-oriented outcome is submitted to the organisation by condensing the most relevant conclusions, the prospective and recommendations for the future office. The audience of the report might not be expert on the topics treated, thus this demands an illustrative and visual format. Here, the technical dossier is oriented to specialists on design, architecture and building engineering. In this dossier, detailed information on an advanced level provides valuable information on e.g. IEQ to experts for later intervention (renovation/new building).

The intervention is the seventh and last stage of a study. But due to the circular SSO process, once it is completed and the workforce has been using the new office for at least one winter season to dry out the building – if necessary – and eliminate the typical failures occurring in the earliest stage of the building operation after the new construction, the SSO model foresees a post-intervention study as part of a continuous assessment plan. It will contribute to evaluate, reinforce and consolidate the progression of the workplace, thereby qualifying for further interventions if needed on a regular basis. The periodicity and number of iterations depend on the evolution of the organisations.

4. DISCUSSION

This section summarises the experience from three pilot tests of office demonstrators, preliminary discoveries from using the SSO-method along with lessons learnt, and finally an outlook into next steps on the agenda.

4.1. Pilot tests at office demonstrators

Offices nowadays are specific to each workplace and branch and typifying an organisation's culture. In a real office environment, people learn, share, enjoy, socialise, behave, and show themselves in a particular way that is hardly reproducible in a laboratory environment. Therefore, only real office demonstrators representing three different branches, all of which in the need of change, were selected for pilot testing.

In Gothenburg, Sweden, data from three office demonstrators, occupied by more than 220 employees, have been incorporated into the research project until the end of 2016: a science park office, an architecture office in the city centre, and a campus office building (see figure 3). They have provided a great opportunity to feed an increasing database with heterogeneous references, while the methodology and its implementation protocol have been improved and validated after iterative testing.

4.2. Tentative findings

The experience with the office demonstrators shows that tentative results point towards three trends that need to be further explored in detail. (i) Firstly, work patterns are remarkable criteria to design the workspace, since most of the operatives conflicting claims originate from a space that does not fit to intended activities or does not support

Figure 3. Pilot studies.

e.g. the required levels of concentration, stimulation or privacy.

(ii) Secondly, users that have the possibility to switch between office settings, tend to occupy the same workstation over time, leading to similar effects in the end to those with assigned workstations. Additionally, the multifunctional use of certain office settings, without well-defined divisions nor behavioural guidelines, causes conflicts between activities that usually take place side by side although they would need different environmental support and operative conditions. A clear example of this are the testimonies of participants who look for an empty meeting room to be able to concentrate on complex tasks because of open areas next to their desk that are often used for mingling and project discussions or a corridor that colleagues tend to use for phone conversations.

(iii) Finally, different workspaces of the offices analysed showed dissimilar indoor climate comfort conditions. According to the IEQ measurements and correlations with subjective surveys, noticeable relations could be identified between e.g. high satisfaction with air quality and lighting, and low satisfaction with speech privacy and daylight (public scrutiny).. However, there is still much bias between objective measurable findings and subjective user perceptions, e.g. measured indoor air quality and perceived air freshness, air temperature, and thermal sensation vote.

Indoor environmental qualities support the uniqueness of the user-centred approach adopted in the SSO model, with tools that are as effectively utilised for evaluation, prevention and strong evidence on empirical results and periodical assessment. This corroborates the strength of the holistic SSO approach in comparison to other studies in the field as well as such studies in planning processes built on none scientific evidence. However, the full potential of the approach can only be expected if the following two conditions apply:

First, it is necessary to put in practise the SSO approach right from the conceptual phase of the building, since being holistic also implies to consider aspects such as the architectural design of the building, building technologies, orientation and even inherent factors to the location, like the shadow projected by surrounding buildings, that in any case will have an influence on the final quality of the built workspace.

Furthermore, the full set of instruments and studies must be considered. As illustrated in figure 4, the SSO approach can be tailored in different modules connected to all life cycle phases and challenges of a building (new and existing).

In any case, further investigations and more detailed results from pilot studies using the SSO approach will be the subject of future publications.

4.3. Lessons learnt

The pilot tests have been an excellent instrument to validate and refine the SSO approach in two directions: the tools and protocols on one side and the data targeted for collection and analysis in the other.

Regarding the tools and protocols, the main opportunities for improvement defined the following three lines of action:

- Usability: Questionnaire and Diary are web-based tools entirely developed from zero and have progressively incorporated improved functionalities required for the studies. Along the process of pilot testing, practical experiences gave valuable feedback to improve. The most relevant improvement in this regard has been a new function to skip the diary session for a participant when out of the office. In the later analysis of e.g. work patterns, it is decisive to know if a Diary session was not completed for that reason or because of non-compliance.
- Motivation: the higher the rates of participation are, the better the recommendations will fit. Thus, a communication strategy has been reinforced at different stages of the timeline to avoid losing the survey respondents in the course of the week.
- Attractiveness: instructions and support information were subject of renovation to minimise the lack of information, motivate participation and engagement, and create a consistent visual identity within the SSO project.

On the other hand, the data collection was massive and fruitful, but a margin for optimisation has been found and certain topics have been further developed or shortened for data collection:

- Facilities: a wider range of explicit references to different office settings, building areas, and services were added to the questionnaire to provide observations and interviews

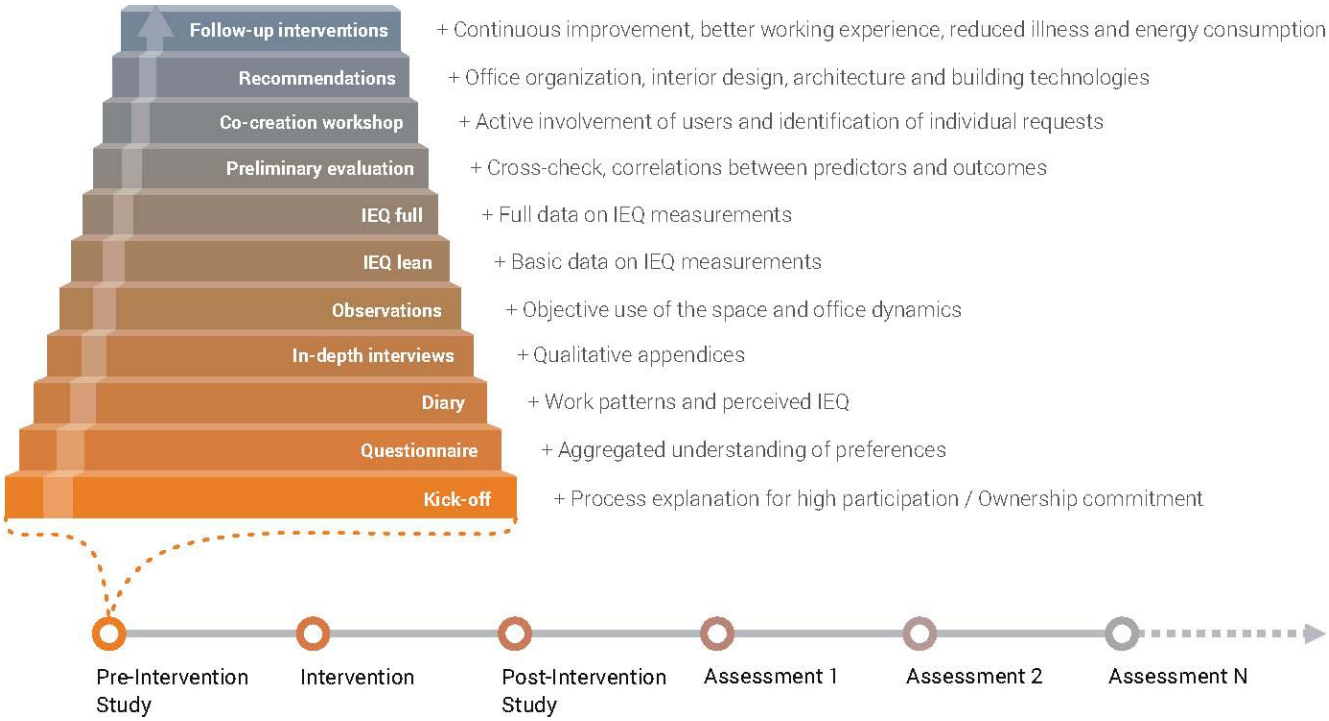

Figure 4. Ladder of success.

with a richer base and reduce the amount of open-end inputs to analyse.
- Work patterns: the resolutions of time and details in activity routines have been increased to be able to outline sharper working profiles.
- Demographics: even though participants cannot be personally identified in surveys and diaries, and that the data collected can only be displayed in an aggregated manner, some questions regarding demographics were reviewed to minimise feelings of privacy intrusion.

4.4. Next steps

Three new studies are under negotiation with new partners for 2017 that would notably increase the database of the SSO project: an office building in Copenhagen dedicated to finances, university office building in Gothenburg, and administrative office from a municipality, also at Gothenburg. The potential number of participants is over 3,300. The three are part of the growing Nordic samples. The medium-term strategy is to keep enlarging, even more, the SSO database with new buildings and locations in Sweden and Spain, to finally cover and compare Northern, Central and Southern Europe climate zones.

From the research side, there is still an open issue regarding the measurement of productivity, since the consistency of self-assessed productivity is very restricted. An additional limitation to this is the rejection of organisations to share internal information such as absenteeism rates and related indexes that could partially offer a more objective picture. Barriers still need to be to overcome and further research is needed.

With regards to the importance of IEQ, a wider focus on IEQ continuous monitoring via permanently installed physical and subjective evaluations is included in the agenda, aiming to cover whole office work areas from individual desks to open collaborative areas on a more constant basis. In parallel, energy performance of the buildings will be monitored and compared thoroughly.

Finally, post-intervention studies and further analysis of results will enable the transference of accrued knowledge into an SSO guideline, a certification system and a user comfort model to support professionals all through the office planning and intervention process.

5. CONCLUDING REMARKS

The three pilot test office demonstrators provided valuable information to keep iterating and professionalising the whole SSO method. The conception of a circular science-based design process, focusing work patterns, individuals and operational needs, revealed superior arguments versus traditional linear approaches to pioneer a new generation of user-oriented, low carbon, and resilient office spaces. As a result, scientific evidence can be provided to encourage investors and office owners to improve employees´ working conditions as a coherent strategy to increase the overall productivity and cost effectiveness.

The creation of new strategies for office work is essential to reduce environmental impacts and social inequity. Through the demonstrators of good case examples, a holistic and a user-oriented approach has a realistic chance to be brought into a very conservative market that is in dire need of innovation, especially where innovation does not spread automatically.

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