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Innovative use of traditional ICT devices to uncover spaces' usage patterns and improve energy efficiency in office buildings.

Uso innovativo de dispositivos TIC tradicionales para descubrir patrones de uso y mejorar la eficiencia energética en edificios de oficinas.

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ABSTRACT: This paper explores an alternative conceptual approach to occupancy and utilization metering and tracking in existing office buildings with dense ICT equipment usage.

Instead of improving building performance by expensive design, construction and renovation processes – the same output from an equal area of workspace using less energy in kWh/m2 – our focus is on increasing output using existing buildings, maximizing utilization through sharing, coordination of working hours from different people, and elimination of unused workspaces. When we think about spatial and occupancy studies, we generally imagine an expensive and complicated setup of detection devices that can capture the needed data. By the contrary, the subject of this study is a buildings' spatial and occupational analysis based on insight derived from the utilization of a traditional PC Power Management tool with a repurposed goal. The information uncovered is the one found when working to power manage big networks of computers. The sudden realization that a network of computers is a network of sensors, reveals itself as a useful and inexpensive tool to detect behavior patterns, unused or abandoned offices spaces, and opportunities for energy savings with simple measures orbiting around moving people and sharing spaces.

The goal of our research is to validate the usefulness (or lack off it) of activity data captured from users in offices' computers to gain information on: occupancy numbers, frequently unused spaces that can be repurposed or shared, and activity from off working hours persons that ask for HVAC, lighting, security and space resources that could be perfectly improved by simple reallocations or movements inside organizations.

We also plan to use this information as a real time input for BEMS and EMS that can ingest this data as a calculation relative to buildings occupancy hence improving building services configuration.

This paper presents the results and their implications for the property industry of real world trials in buildings of 2

Catalonian cities, including Barcelona.
Previous studies in the UK and Finland showed how actual desk use is only 45% of capacity during the working day. The results of the initial trials support this statistic in the Catalonian workplaces studied. Conventional methods of reducing energy use by including presence detection and zoning in building energy management systems offer a solution to energy waste, but they ask for big budgets and long implementation periods.
The device-based method applied here offers significant potential advantages over conventional sensor based energy optimization approaches. It is substantially cheaper to implement because it 'senses' presence or activity using existing technology of employees' devices. Perhaps more significantly, optimization is based on an understanding of actual working practices and specific needs of employees, rather than reacting impersonally to aspects of their behavior - e.g. presence or movement detection. This allows users to feed their views into the optimization process and have it suit their preferences, removing the barrier of having to adjust to a new technology which they may not fully understand. The capacity to assess each user's situation separately offers a 'third way' of partial or phased flexibility, applied only to those it suits or helps.

The sustainability implications of working to this model relate to the potential for a reduction in total workspace demand and a resulting drop in energy and resource use. Further research is required to explore new business models for sharing space, service and maintenance costs, to ensure the workspace made free by optimization can be used in place of additional new-build..

1. INTRODUCTION

This paper introduces an alternative approach to achieving energy- and resource-efficiency in the built environment. Instead of improving the technical performance of buildings by replacing elements of its structure, we examine approaches to optimise utilisation of existing stock through better understanding how users consume a building. This understanding is achieved by application of an existing PC-based user activity monitoring software – Verdiem (PC Power Manager™) – plus additional layers of data interpretation to enable spatial analysis of workspace use and its associated energy services. On the basis of the analysis, options to rationalise space use and energy system management, according to active, real-time demand, are proposed.
The results discussed here are based on two initial trial case-studies of government offices in Barcelona City itself and Sant Feliu de Llobregat City (Barcelona). These case-studies were aimed at developing a methodology and protocol for applying the analysis on real buildings, to support decision-making actions towards rationalising workspace and energy use.

2. BACKGROUND

As Janda (2009) bluntly puts it: 'Buildings don't use energy, people do.' The user is the common thread that leads to emissions. Taking the user perspective, independent of any infrastructure, presents a base for optimising carbon impact to behaviour. It could also increase overall impact on building related emissions by reducing reliance on building space that is often unused.

According to a report by the Low Carbon Workplace (Deas, 2011), average office desk occupancy in UK public offices is only 45%. A similar situation exists in government estate buildings in Finland (Nordic Built, 2012). A project report by Cisco (Cisco, 2007) on an office rationalisation plan to flexible use reported a reduction in building costs (rent, construction, utilities) due to reduced total floor area for an equivalent number of staff of between 37 and 42%. A recent Carbon Trust report (CT, 2014) into the rise of teleworking practices in the UK reflects on the impacts of employees working out of office, highlighting:

"If office space is properly rationalised to reflect this, homeworking can also significantly reduce office energy consumption and rental costs."

However building design processes, based on conventional metrics of m2 per person, take no account for how much that conditioned space is utilised in reality, and assume 100% utilisation in specifying services (Dooley, 2010). Focusing on users, and only providing for their real needs, could provide a framework towards removing this issue.

The first step in this process is to understand use and occupancy patterns of office working environments. Dooley stated the need "to develop integrated occupancy measurement and control technologies for commercial buildings" (Dooley, 2010). Campos et al (2010) report on the Enprove project, which demonstrates the value of accurate data on how a building is used to predicting savings and return on investment for installing technological measures such as intelligent lighting controls.
Though some real time monitoring and adjustment of energy systems is possible – e.g. presence or movement detection – these systems are expensive, can be disruptive to work and are difficult to tailor to the particular needs of each individual building user. Coleman et al (2012) discuss a system linking existing Wi-FI with wearable RFID badges and energy monitoring hardware, which although simpler, still represents additional investment and employee interference.

The Workspace Optimisation energy Fix (WOeFix) protocol is an attempt to investigate an alternative based on PC-user activity monitoring data, generated by the Verdiem software, rather than building occupancy monitoring. It also has the advantage over mere presence detection of tracking when employees are actively working, not just passively present in the building, which can aid assessment of the building's true contribution to an organisations output. The protocol is built on a premise of using the already installed technology, analysing active use profiles and adapting spatial and temporal factors of the building to fit these profiles. Technological building upgrades remain an option for later consideration, after benefits from non-technological measures such as zoning, have been applied.

Also, workspace optimisation analysis leads on to the emerging trend of flexible working, of which teleworking is one example. Introducing flexible working to existing offices can be more problematic (e.g. Davenport & Bruce, 2002; Robert & Börjessen, 2006). A partial or phased introduction, enabled by our approach, allows a process of behavioural 'nudging' to take place (Thaler & Sunstein, 2009) where a portion of workers prepared to go flexible demonstrate and promote the approach to unsure colleagues.

However, taking a wider urban perspective, turning administrative buildings from static to dynamic space resources, users can be freed up to locate their activities as it best suits them and their colleagues or clients at any given time. Buildings, travel, office resources might then be used on a temporary basis for only the number of hours or days that they are specifically required. All these resources might then be shared between organisations utilising a resource cloud in a form of collaborative consumption (Botsman & Rogers, 2009). The CDP (2011) suggests that linking buildings and technology in this way is an example of the necessary viewing of resource constraints due to the Earth's limited natural resources as an opportunity to generate increasing value from fewer resources.

3. METHODOLOGY

By installing a PC Power Management agent from Verdiem Software in all the computers, we can analyze the power states data metered from them, jointly with users' activity. Physically representing the state (ON or OFF) and the activity (active or inactive) in the office layout plan, we can grab information about the office spaces utilization. We then relate it with a few important questions that can be answered in a really simple and fast manner because of the usage of computers as sensors that are already deployed in the offices (without having to physically install new sensing devices).

This questions are:

1. Which are the computers that are least used? This relates to the following sub-questions when we detect an unused device:
   1. Do we need that computer?
   2. Do we need that desk?
   3. Do we need that space and HVAC + lightning and building services related to it?
   4. Do we need that role?

2. Which is the "occupancy level", acquired from computers usage?
   - 2.1. Can't we better adapt the space we are paying for, with the real occupancy metered?
   - 2.2. Can't we distribute people in a better way, creating shared spaces that can allow a more reasonable use of the building?

3. Who are the most active and persistent at their desktops?
   - 3.1. Which is the size of this stable set of workers and which are their timelines?
   - 3.2. What is their spread around the organisation? Are they mostly on the same few teams, working together, or are they spread throughout different teams/departments, not working together?
   - 3.3. In short, how easy or difficult would it be to place persistent desk workers in the same area of the building?

4. Who are the "off hours workers"?
   - 4.1. Can't we group them, thus reducing the building services needs while giving them a suitable working space?

4.2. Could they work from home 'off hours' - what change in ICT equipment/facilities is required to enable this?
4.3. Who are the ones that have more intermittent computer usage?
4.4. Can't they make better use of mobile or shared devices?

4. CASE STUDIES

Sant-Feliu de Llobregat is a provincial city in the outskirts of Barcelona. The main administration building houses around 70 desked employees. (Fig.1)

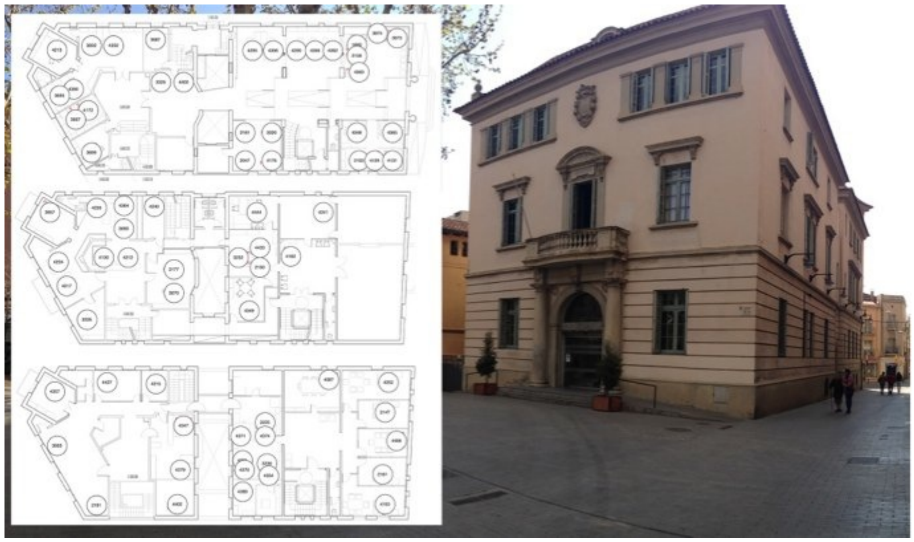

Fig. 1 Sant Feliu de Llobregat City Council

Data was collected for the case study using the Verdiem Surveyor software during February 2014.

Barcelona City Council is much larger and the administration is housed in multiple buildings to a total of approximately 8,000 workspaces. A single building was used to conduct the initial analysis (located at Av. Diagonal, 220) housing approximately 600 employees (Fig.2).

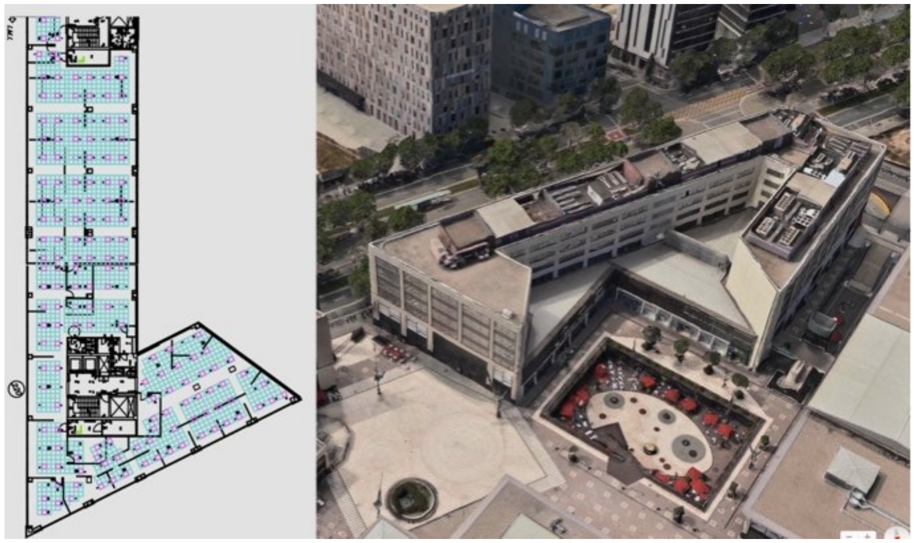

Fig. 2 – One of Barcelona's City Council Buildings

Data was collected for the case-study using the Verdiem software in April 2014, with two weeks of data starting Monday April 7.

In both cases the monitoring was complemented by a 'walkaround' visit to the site.

5. PRIMARY RESULTS AND ANALYSIS

The first iterations of data analysis led to data presentation in three categories:

1. Average Occupancy Percentage – i.e. the number of workspaces in active use at any given time as a fraction of the total number of workspaces
2. Classification of activity profiles based on a typology of individual occupancy patterns
3. Time series visuals mapping current occupied workspaces onto the office layout plan

The average occupancy percentage is a simple measure of the number of workspaces in active use throughout the monitoring period. The graph below shows the average over a week at the Barcelona office (Fig.3)

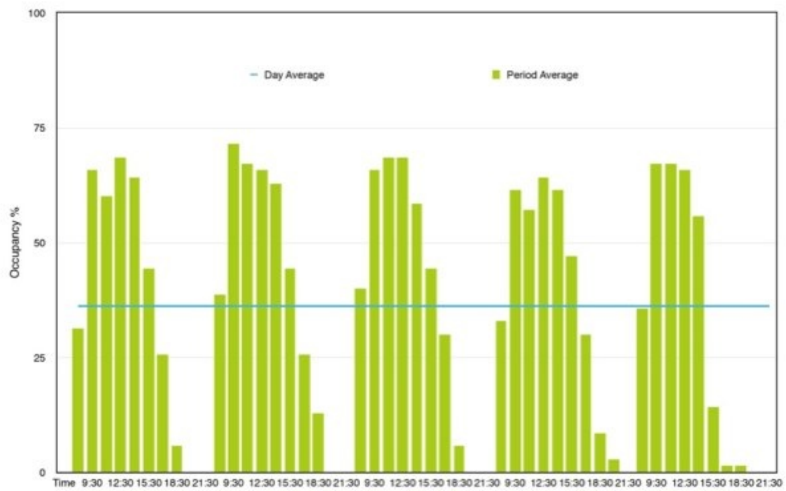

Fig. 3 – Average active computers within 90' periods (8 to 23 M-F)

The daily average rarely reaches above 50%, in line with the previous studies in UK and Finland, referenced earlier.

Next it's same information for an average day, highlighting the percentage of serviced workspace that is not utilised of the total areaday (m2h). This represents the maximum theoretical potential saving in energy and space cost through optimisation (Smax) (Fig.4.)

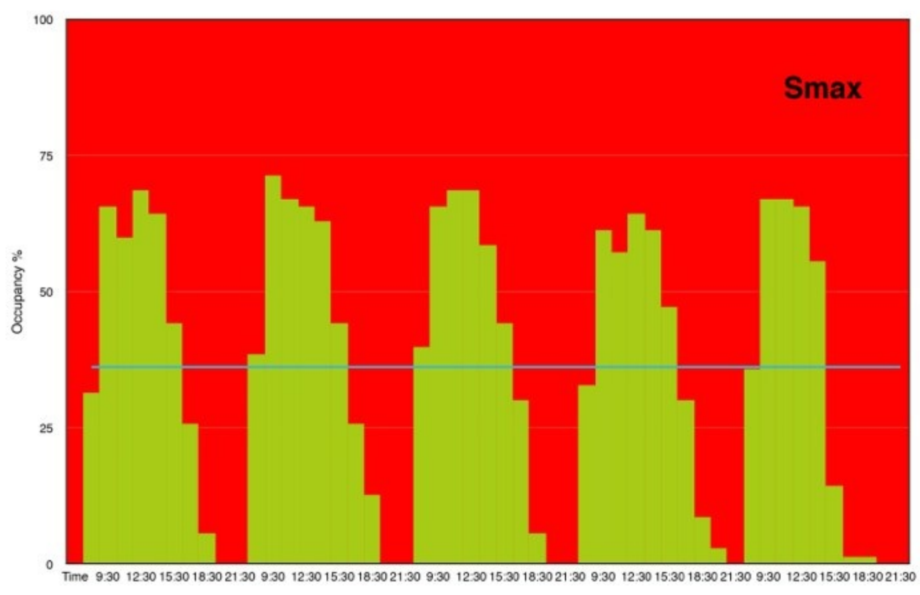

Fig. 4 – Maximum theoretical savings

We then needed to generate a reduction factor to apply to this Smax, based on what can reasonably be achieved without compromising the ability of all staff to conduct their work comfortably.

To determine this factor we analysed the variation and comparative frequency of the different individual occupancy patterns, to determine the potential for:

1. zoning - i.e. locating users of similar profiles in one zone, which can then be shut-off outside in-use hours.
2. sharing workspaces between multiple users - i.e. a morning user with an evening user

A simple option would be for the factor to represent a margin of, say 10% about the highest recorded occupancy rate, above which the unused space and energy can be saved.

A more advanced option would be to statistically assess the correlation of user profiles: a high correlation along a single profile indicating low potential for workspace sharing; a low correlation or scattered profiles indicating sharing could be disruptive and only applicable on a 100% flexible workspace policy; whereas high correlation along 2 or 3 distinct profiles suggests significant potential for optimisation through workspace sharing.

However, two factors suggest caution towards attempting deep statistical analysis. First, considering the aim of this tool to provide advice on energy-efficiency opportunities, decision-making may be easier based on viewing the data as presented, rather than the results of abstract behaviour analyses. Secondly, a reorganisation will affect the individual and how they carry out their work, which may play a greater role in its success than attempting statistical perfection.

USERS' PROFILES

Users are classified as “Morning only”, “Morning + 1 afternoon per week”, “Full Day” and “Sporadic” (Fig.5)

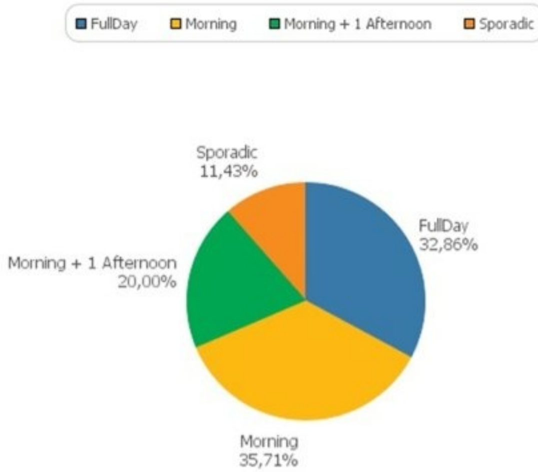

Fig. 5 – Percentage of each profile

Paying attention to this simple graph we could predict ample room for optimisation because only 32,86% of the users work the whole day.

GRAPHIC EXAMPLES OF METERED USER ACTIVITY FOR EACH PROFILE

Fig.6 shows the different shape of the activity level M-F.

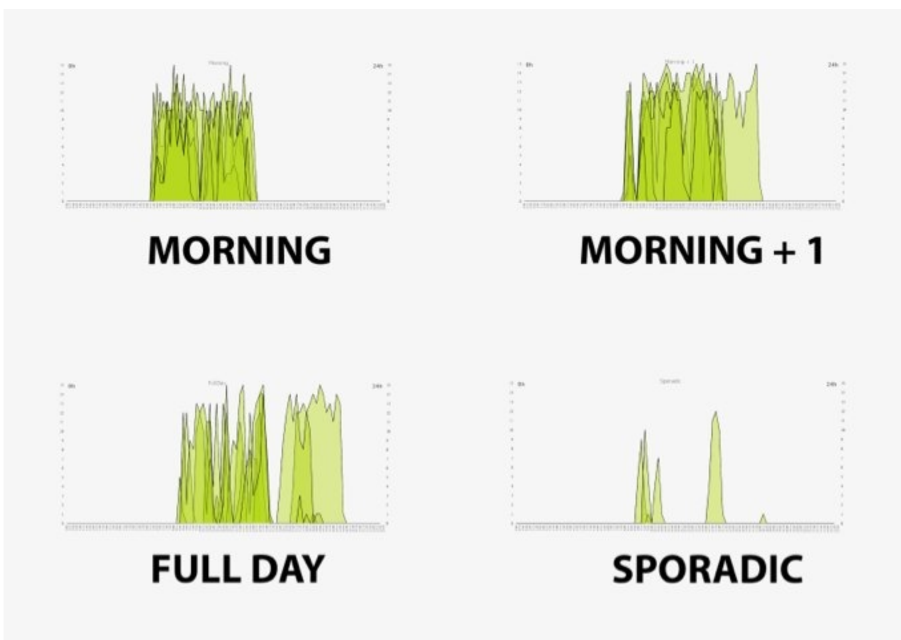

Fig. 6

Once all the devices are classified by their main usage profile we study best ways of spatially grouping users to improve resources efficiency with a very low level initial investment. Users with a sporadic profile suggests they can use tablets or mobile devices, and / or share common workspaces.

Finally, time series visuals of mapped data enabled usage patterns to be viewed spatially and collectively. By viewing user activity maps in a 'movie' over a time period of one day or one week, we were able to observe shifting patterns of where activity is concentrated at a given time. Also, locations and areas that remained unused for a sustained period of time were apparent. Finally, the location spread of outlying users active before 0900 or after 1700 was shown, allowing assessment of the level of relocation required to place these users in, for example, a single out-of-hours active zone.
In the case of Sant-Feliu, little out-of-hours activity was observed, though significant workspaces (29%) were used less than 10%. There were a number of spatial outliers - a high-activity user surrounded by low activity workspaces

In the case of Barcelona, a low numbers of out-of-hours users caused energy systems to remain on throughout the building. Relocating these users into a smaller out-of-hours zone and adjusting energy control settings accordingly, presented an opportunity for an estimated €1800 annual electricity savings per floor, without investment. This estimated savings are based only in existing lighting control without adding any other likely potential savings derived from other effects.

6. DRAFT PROTOCOL

The following protocol has been developed to apply WOeFix in an energy and workspace optimisation plan for an office building.

1. **Stage 1, using only activity data, prior to mapping:**
   - 1.1. We analyze the activity database to extract an “occupation from PC activity index”. If low, it infers a high potential for improvement through optimisation.
   - 1.2. We classify the users in different profiles, based on type of activity, and produce a report with counts on those sets.
   - 1.3. We calculate estimated savings: Smax * Reduction Factor
2. **Stage 2, using mapped usage and occupancy data:**
   - 2.1. We plot the location data and do the movies to analyze re-location possibilities. Step one, floor by floor. Step 2, intra-floors. (Fig.7)

Fig. 7 – Current location of users shown by profiles

2.2. We estimate lighting control based in zones optimization, we calculate result in savings, and we do the same with HVAC… Fig. 8 shows reallocation proposal based on users matching profiles.

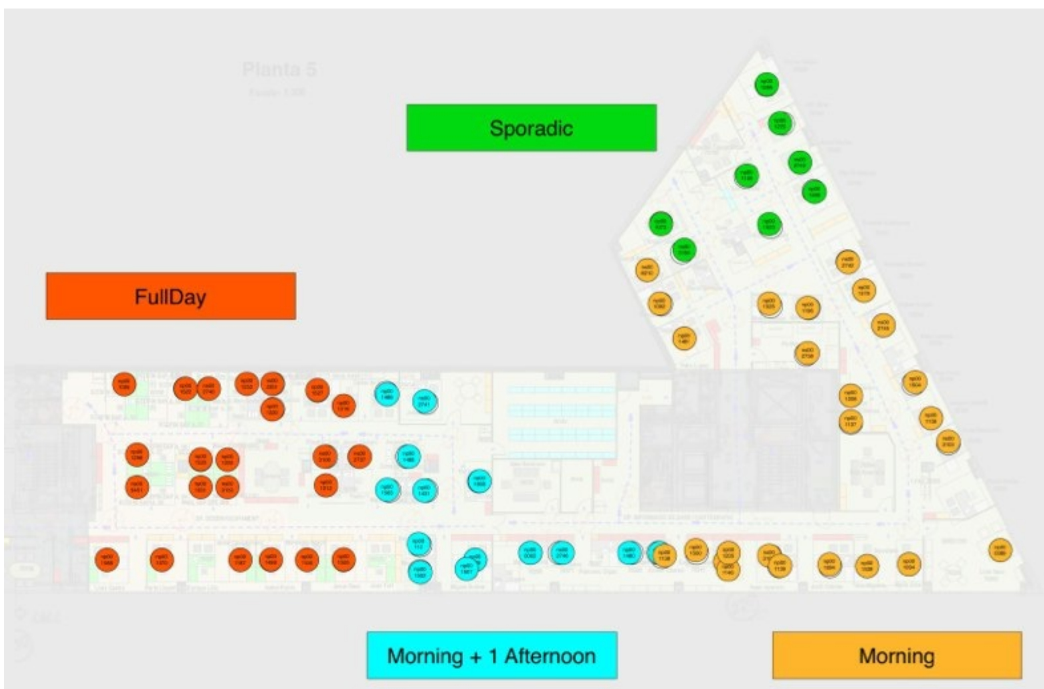

Fig. 8 – A theoretical ideal relocation layout

2.3. We calculate raw square meters saved by shutting down unneeded spaces.

7. IMPLICATION / DISCUSSION

The results so far are too preliminary to judge the method successful. Occupancy rates in both case-study buildings reflect reference figures at around 50%, suggesting significant potential for savings through optimisation, as indicated in the literature.
The analysis provided a platform to accurately assess the impact of lighting controls, based on occupancy detection. By recording the length of off/on periods of active use, mapped onto the lighting layout the performance of occupancy-reactive dimming can be predicted and energy savings calculated. This information provides building managers with a reliable assessment of the expected return on investment in advanced controls. Further investigation will uncover if similar assessments can be done on HVAC controls.

The spatial data collected demonstrated the complexity regarding activity patterns of multiple users. Further statistical analysis of the spread of activity - both temporal and spatial - may aid understanding of how usage and occupancy profiles interact. This in turn could help demonstrate the value of the tool in generating a metric to assess the practical feasibility of achieving the potential savings through optimisation, without compromising the individual usage profiles as determined by specific work demands and user decisions.

On the wider implications for urban planning, the analysis supports a deeper evaluation of the possibilities for rationalising use of existing workspace, before prescribing the need for new development. A long-term aim of this work to investigate opportunities for sharing of building resources, taking into consideration evolving mobile working practices, will provide a valuable contribution to this discussion.

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