DEVELOPMENT OF PROTOCOL FOR SUB-METERING FOR SIMULATION MODELS OF SHOPPING CENTRES

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ABSTRACT

The study investigates the efficiencies and inefficiencies associated with the everyday management, operation and use of shopping centres and aims to identify the drivers, barriers and potentials associated with the operation of shopping centres. Its main focus was to track inefficient use and user implications in complex buildings (shopping centres). First, the main predictor variables and performance indicators were identified.

A protocol for sub-metering of energy consumption and flows (mainly heat and electricity, but also other sources and common services) was defined as necessary basis in order to be able to track inefficient use and user implications. User profiles were split into sub-categories, owners, tenants (shop owners, differentiating by size and type) and end-users (shopper, with appropriate differentiation) are three minimal differentiations.

The proposed method provides a solid basis for performance based economic models that have to be introduced in order to be able to apply cost-effective refurbishment investments. The results of key performance indicators provided valuable input in the decision making process for deep retrofitting plans. Different proposals for visualization of results (feedback to managers, tenants, customers) were investigated and are discussed.

Keywords: shopping mall, sub-metering, energy flows

INTRODUCTION

Shopping centres are not interchangeable with other kinds of complex buildings, such as office blocks, hospitals or schools. The character of shopping centres, form, function, usage, and users has implications for energy use. To support the understanding of what causes the main inefficiencies in energy usage and how to develop the best solutions sets, a definition of shopping centres was developed, based on existing literature. The definition chosen in this study describes a shopping centre as "*a formation of one or more retail buildings comprising units and 'communal' areas which are planned and managed as a single entity related in its location, size and type of shops to the trade area that it serves*" [1]. The definition gives an indication of the main form and function in shopping centres. In addition, location, type of development, the size and the GLA, the type of anchor stores and the trip purpose are all aspects that have been used to indicate the needs that a shopping centre serves within social and physical context, these are presented in Table 1. Climate and regional differences have implications for retrofitting practice and the definition and supporting table present climatic and regional differences and are registered in the description of ten representative reference buildings [1].

In general the shopping centre industry is used to key performance indicators (KPIs). Example of KPI for a Shopping centre real estate company are: Total property return, Occupancy, Like-for-like, NRI (net rental income) and Growth in EPS (earnings per share). This work will identify the main predictor variables and performance indicators found in shopping centres in a context with user and occupant expectations and requirements. Form

follows function to a large degree in shopping centres. However, the needs of retail activity and the requirements associated with the different stakeholders and their typical functional patterns actively influence shopping centre architecture and energy consumption [3].

METHOD

Sustainable shopping centres are more than simply energy efficient, they are environments that are accessible to all sides of society irrespective of buying power, social class or disability. This paper therefore opens with a discussion of architectural qualities in shopping centres, because architecture at its best is often understood as a combination of technology, functionality and aesthetics. The paper develops performance indicators based on the technical functionality of shopping centre architecture, for example flexibility and universal design, in short meeting user needs. Subsequently, predictor variables and performance indicators associated with several aspects were examined.

RESULTS

Architecture, typology and layout of shopping centres

Architecture encompasses technology, functionality and aesthetics. In this section, architectural form has been considered in context with user and occupant expectations and requirements to build a basis for energy performance indicators that relates to shopping centre form, layout, users requirements and cultural context. There are different types of shopping centres (see **Erreur ! Source du renvoi introuvable.**) and there is a typology associated with the usage that different areas in shopping centres are put to, functional patterns and stakeholder groups are associated with the areas. The different shopping centre types and typologies may vary according to for example size and use, for example it may be expected that speciality centres will have smaller circulation areas and less storage space than regional centres, and some centres do not have restaurants, staff rooms or atriums [2]. However, if we take into account the variations found within the main shopping centre types, there are certain areas that may be considered standard for all shopping centres. The table describes the five main areas in shopping centres, their usage and different locations within a centre and shows an overlap in usage, for example not all retail takes place in clearly defined retail units; some take place in common areas in temporary or permanent units. Restaurants, food courts and cafes may be found within retail units and on occasion stores may be found in restaurants and cafes. In addition, centres that offer leisure activities, or specialised functions like conference facilities, are typologies not covered in this overview. Typical examples which impose other usages include cinemas, bowling alleys, or swimming complexes. Hotels or apartments may also be located within shopping centres. For these typologies additional performance indicators apply which are not covered.

Energy use and flows in shopping centres

Table 1 offers insight in the broad range of activities which take place in shopping centres, giving customer satisfaction requires a broad range of services from shops, toilets and deliveries, to technical rooms, child minders, cafes and car parks. The range of activity requires a complex and flexible physical structure, one that allows for, amongst other things, changing retail, demographic and technical needs.

Shopping centres are complex buildings with specific needs. The use that different areas are put to affects energy consumption, whereas the different functional patterns and stakeholder

groups influence energy use. They are also associated with specific requirements that make it relevant to consider different types of performance indicators.

Typology	Main usage				Location			
					Common areas	Shop/ retail areas	Behind the Scenes	Outdoors
Common Areas	Circulation	Main horizontal circulation	Vertical circulation	Emergency exits	**Main usage areas**	Within retail units and stalls	None	Benches paths, play areas and other
	Entrance	Main entrance	Side entrance	From car park				
	Sanitary	Toilets	Child care					
	Parking	Entrance	Circulation	Parking				
Restaurants/ cafes/ Food courts	Entrance	Seating	Service	Food preparation	Atrium location	Food serving in-store and restaurants	Kitchens, prep, storage	Pavement cafes
Shops/ Retail/ Other	Entrance	Sales	Service	Staff rooms / storage	Atrium, corridors	**Main retail areas**	Storage, staff rooms	Temporary/ permanent
Behind the Scenes	Entrance	Trolleys	Trucks		None	Storage, staff rooms and waste in some units	**Main usage areas**	Delivery waste storage
	Storage	Services	Waste					
	Technical rooms	Pathway	Shafts	Sanitary				
	Circulation	Horizontal circulation	Vertical circulation	Emergency exits				
Outdoors	Restaurants/ cafes	Entrance	Seating	Service	Benches, paths, play areas and other	Temporary or permanent retail units, or stalls	Delivery and waste storage	**Main usage areas**
	Parking	Circulation	Parking lot	Service				
	Leisure	Resting/ Recreation	Seating	Other				
	Delivery area	Containers						

Table 1: Typical Areas in Shopping Centres [2].

In the scope of this analysis both indicators and requirements with a direct or an indirect effect on energy consumption in shopping centres are identified. When defining the relevance of performance indicators; legal requirements (i.e. for work environment), ownership or authority over parts of the centre, and cultural context also come into play. Therefore, six performance concepts are identified which form the structure of the next sections, all with contextual relevance to energy use and supply of energy in SC:

- Energy follows function
- Energy follows form
- Energy follows user needs

} Functional element sub-division

- Energy follows stakeholders
- Energy follows organization
- Energy follows availability

} Organizational element sub-division

As a result of the underlining complexity of performance requirements in SC, it may also be useful to distinguish between causes of energy use within a functional sub-division, meaning energy divided by the functions which it is used (by end use or supply system), and organizational sub-divisions of energy use distinguished by who pays for the energy and thus is related to billing practice, tenant agreements, and contracts with energy supply carrier companies.

The first three are mainly linked to the demand side and indicators that represent the requirements that can be found in norms, standards and the like. While different stakeholder groups, organisation and contextual aspects like climate and energy availability, also define the relevance of performance indicators, and suggest which priorities should be given when performance requirements are in conflict. The latter interest groups and contextual aspects also form billing practices, sub-metering and indicators for dividing the operational energy costs.

Protocol for sub-metering

Figure 1 illustrates a functional sub division of energy end use within a shopping centre. Starting with the energy supply and the technical services in place, the energy use associated with heating, cooling and electricity are structured by end use. The diagram is easiest to comprehend for centralized HVAC systems, but in principle the structure is the same for all installations localized in tenants' retail space. In a typical shopping centre there will exist several heating, or cooling loops and many electrical subdivisions (distribution boards) on top of various end uses of energy.

The illustrated processes are usually in the control of facility managers and technical staff. A multitude of performance indicators can be related to this structure. Some performance indicators are important in the design and commissioning of the systems, other are of use in the day-to-day running of the centre. Reading the diagram from left to right, the potential of increasing energy efficiency lies both in production, distribution and end-use.

Energy can be considered to follow function because energy in the end is used to meet requirements defined by the activities that take place in a shopping centre. In a SC, requirements are diversified by the type of tenants (shops, retail, restaurants, cafes, etc.), by the size of tenants rental space (stalls, retail units, independent anchor stores etc.), or by the type of spaces (common areas, offices, storage etc.). The different activities can be characterized by functional patterns for various groups; – opening hours for customers will differ from operational hours for technical services and lighting. Facility operation has to meet the requirements of staff before the shopping centre opens to the public. In shopping centres many tasks are performed outside of opening hours which require maintaining health and safety for the workers. Examples are cleaning, sanitation, loading and re-stocking of goods. In relation to this, the ratio of full operation of HVAC and lighting vs. opening hours or service hours is one index that could be used as a performance indicator.

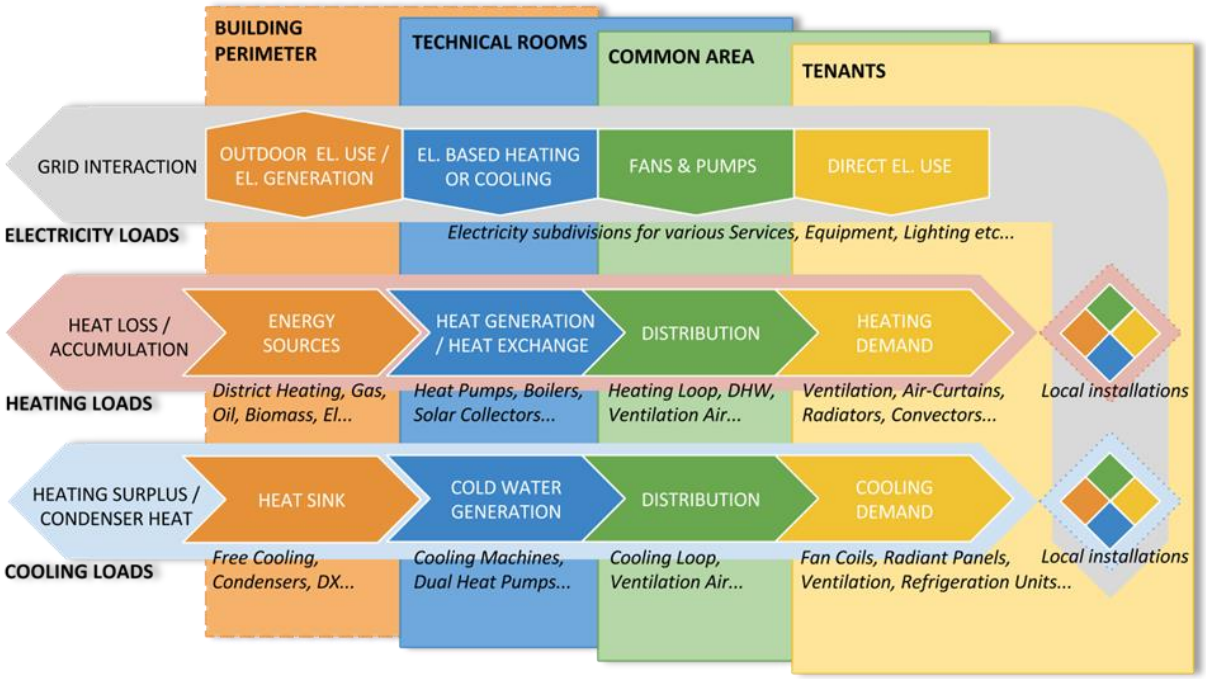

Figure 1 – Monthly wind velocities of different measurement stations

DISCUSSION

The shopping centre market has changed from a fairly homogeneous, mass consumption market to one that is fragmented according to for example taste and lifestyles, reflecting a diverse and changing society. Shopping centre architecture therefore needs to meet needs of consumers who are more sophisticated and demanding. During the rehabilitation process it is important to keep in mind the four main stakeholders groups, namely customers, management, tenants and community. An integrated design process is needed that takes into account the goal to develop future markets where good architecture contributes to low-energy use, attractive trading jobs and meeting spaces, and thereby supporting the activities of all four groups.

Energy follows form

In typical shopping centres the retail units are often heated, cooled and ventilated separately from the common areas. The same retail units are often also connected to the central spaces by large open doorways through which air, odours, light, and noise exchanges occur, effectively linking the different spaces.

Energy follows user needs – workers & customers

It is challenging to meet performance requirements, to keep within accepted limits of comfort and meet retailer needs in such an open indoor environment, where different spaces inside the shopping centre are effectively linked (as described in the previous section). However even with greater energy use focus on accessibility and a wide range of issues will remain of primary importance, not only because of retail needs, but also because, as mentioned earlier, sustainable shopping centres should be accessible to all sections of society.

Energy follows stakeholders – decision makers

Comfort needs, however, are also socially constructed. In the design process, operation, meetings between tenant associations and management, labour meetings performance indicators can be important quantitative statements to meet user needs with regard to comfort and ensure high energy performance.

Energy follows organisation

Organisational forms can be observed in Real estate companies, property companies, management companies, facilities companies (outsourcing or within the same owner company) and tenant associations. Contracts between those organisations and the indicators used in those agreements are often based on KPIs which offers potential for introducing energy intensity related KPIs.

Energy follows availability

Nowadays, it is a challenge to transform the current energy system into modular power generation in order to improve the quality and the reliability of the electricity supply. The renewable energies and efficient solutions can overcome the oversizing problem of the electrical infrastructure for meeting the energy demand peaks as well as the energy transmission losses. However, the incorporation of renewable system in shopping centres must take into account that some problems in the supply can appear given its dependence of the climate conditions as well as the affections in the quality of the grid since they can generate frequency and voltage fluctuations and outages. Furthermore, any interaction in the grid must consider the grid capacity for admit new compounds.

CONCLUSION

In the scope of this analysis both indicators and requirements with a direct or an indirect effect on energy consumption in shopping centres were identified. When defining the relevance of performance indicators; legal requirements (i.e. for work environment), ownership or authority over parts of the centre, and cultural context also come into play. Six performance concepts were identified which have contextual relevance to energy use and supply of energy in SC. As a result of the underlining complexity of performance requirements in SC, it may also be useful to distinguish between causes of energy use within a functional sub-division, meaning energy divided by the functions which it is used (by end use or supply system), and organizational sub-divisions of energy use distinguished by who pays for the energy and thus is related to billing practice, tenant agreements, and contracts with energy supply carrier companies.

A possible task for the future could be to identify if and how relevant energy performance indicators can be incorporated in contracts, or other forms of agreements between the stakeholders.

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