Smart City Block: a new level of intervention for city renovation and reducing energy consumption

Klopfert Frédéric, Mortehan Olivier, Hélène Joachain and Caroline Lhoir

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The Smart City Block project aims to promote renovation at the level of a city block. It thus directly tackles the insufficiently explored “meso level” where stakeholders with different motivations should interact to achieve a common goal. This interdisciplinary project proposes a variety of technical solutions including insulation techniques and highly energy-efficient equipment but also exploits energy savings that can only be achieved by behavioural changes related to new living organisations. As the proposed approach cannot be applied systematically to any city block, the first step was to develop a methodology for determining where such a block renovation is feasible, within the 5000 city blocks of Brussels.

In order to evaluate the acceptance of households, a survey was conducted on four city blocks in Brussels, representing over 450 households. It was therefore necessary to expose the possible solutions in a comprehensive manner for a diverse set of inhabitants. A list of “elements” (including items such as architectural, building performance, HVAC, common living spaces, equipment and gardens or vegetable garden) was produced by specialists (engineers, architects, urban developers and sociologists).

The last section of the paper provides the survey methodology and some early results showing inhabitants low attractiveness of energy saving technologies and limited desire to share energy consuming activities.

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Abstract

The Directive 2002/91/CE on the energy performance of buildings requires that by end 2020, all new buildings within Member States are “nearly zero-energy”. Though this is technically feasible for any new construction, the problem of reducing the energy consumption of the existing building stock seems much trickier. Can or will all owners invest to renovate their houses? Are information and financial incentives sufficient? Will individual cost-benefits or return on investment calculation at micro level be enough to overcome the barriers to renovation?

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Introduction

Since a few decades, climate change, scarcity of energy resources, cost of energy are becoming increasingly important in EU Member States political agendas. The envisaged solutions to reduce energy demand are mainly based on three pillars: the promotion of renewable energy\(^1\), the promotion of energy efficiency\(^2\) and finally promoting energy savings by behaviour changes\(^3\).

As the two first pillars are essentially technical they have seamlessly been integrated in coherent policies. Within the scope of households and Small and Medium Enterprises SMEs we are interested in, the Energy Performance of Buildings Directive (2010/31/EU) clearly achieves this for new buildings or “major renovation”.

The behavioural change pillar is treated quite separately and in a manner that is dependent on the underlying theoretical behavioural frameworks. With theories such as the planned behaviour (Ajzen, 1991), behaviour changes should be triggered through increased information on energy consumption and/or grants to reduce investment barriers, while the social practices theory (Reckwitz, 2002 and Shove & Walker, 2010) will essentially focus on collective symbols or energy challenges to induce change. A kind of dichotomy can be observed between rational or individual-based theories and the social or group-based theories. The debate is however not only theoretical. Indeed the former aims at inducing change at the micro-level (i.e. households or SMEs) whilst the latter addresses the macro-level (large groups such as towns, industry or the society in its whole).

The Smart City Block (SCB) project aims at introducing a meso-level on which both technical and behavioural aspects can be tackled simultaneously. Although this approach does exist for social purposes such as redevelopment of specific urban areas (e.g. Dampoort, Ghent, Belgium), to our knowledge, there is a lack of research on aiming at this specific level for the purpose of reducing energy consumption.

The meso-level introduced by the SCB project is a city block. The objective is to propose a mix of technical and behavioural changes that can lead to both energy savings and increased quality of life.

Six major questions to be answered constitute the backbone of our four-year research:

- What is the technical and social offering of a SCB?
- Are some regions or parts of a city more suited to the introduction of SCB than others?
- What is the social acceptability of such solutions?
- What kind of incentives are necessary to promote SCB taking into account the tenants/landlords relation?
- What is the potential of energy savings of creating SCB?
- Which are the stakeholders than need to be involved to develop SCB?

This paper describes the methodology used to answer the first three questions.

The first section gives a short overview of the set-up, organisation and the main milestones of the SCB project. The description and the methodology used for defining the offering of an SCB are given in section 2. The third section describes the methodology developed for locating areas in the town that are potentially more adapted for

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\(^1\) Such as the climate and energy package (Directives 2009/28/CE to 2009/31/CE)
\(^2\) Such as Directives 2012/27/EU on energy efficiency or 2010/30/CE on labelling of energy-related products
\(^3\) Such as the Intelligent Europe II program
SCB projects. The paper mainly focusses, with its section 4, on the social acceptability of the SCB concept by exposing the results of the survey carried out in 2012 on 450 households from the Brussels Capital Region (BCR). The final discussion and preliminary conclusions of the SCB approach close this paper.

**Engineers and sociologists**

The Directive on the energy performance of buildings requires that by end 2020, all new buildings are “nearly zero-energy” (EPB Directive 2010/31/EU, Article 9). Though this is technically feasible for any new construction, the problem of reducing the energy consumption of existing building stock seems much trickier. Is near zero-energy renovation technically possible? Can or will all owners massively invest to renovate their houses? Are information and financial incentives sufficient to accelerate renovation in existing cities?

With a city block perspective, answers can be quite different than by assessing households individually. However, the complexity of proposing renovation at a city-block level requires more competences and specialists coming from many different disciplines are necessary: engineers and architects for the renovation and insulation of the envelope, city planners, geographers, sociologists, psychologists, economists, lawyers, etc.

The SCB project was initiated in the Free University of Brussels⁴, facilitated by the fact that all the disciplines are available in one place. A coordination team including an engineer, an economist and a sociologist was selected for this four-year project. During the first year of the project, 40 researchers, PhD students and professors collaborated, resulting in three intermediate reports: a catalogue of SCB elements (section 2), a typology of BCR building stock and inhabitants (section 3) and a first survey on the social acceptance of SCB (section 4). The objective of the year 2 and 3 is to evaluate the potential of energy savings through the SCB concept, carry out a more extensive survey, analyse stakeholder’s interactions, draft specifications for one or more SCB in Brussels and propose innovative financing mechanisms.

**The impossible list of possible elements**

Just pick out one city block of the 5000 ones in BCR and imagine what can be done to save energy. The exhaustive list of possible actions is almost impossible to draft. However, a reasonable list of so-called “elements” needs to be identified and this limited lists needs to be sufficiently representative of various types of renovation patterns. An “element” has been defined as any physical element – building, inner or outer space, infrastructure, equipment or resource – that can be used within a renovation project to increase energy efficiency, environment friendliness, social wellbeing or economic advantages. In many cases, elements can be linked together in scenarios, because they only make sense together, either for technico-economic or for social reasons. These “scenarios” are defined as a combination of elements that are either called “technical scenario” if they are linked by a physical flow (e.g. electricity, gas, heat, water, etc.) or “human scenario” if they are linked by social practices or if they bring new meanings or new modes of living together.

The methodology developed for this purpose consists of the following steps:

First, a series of individual and disciplinary brainstorming sessions were set up to gather idea of specialists in each topic. The resulting matrix analysed elements (category, potential advantages and types of service) and their links (flows, data required, management, etc.). The concepts of elements and scenario were fine-tuned during this phase.

⁴ Université libre de Bruxelles
Second, an in-depth study was carried out by the coordination team to perform an initial selection of elements and draft a template for the systematic description of each element. The elements were grouped in three major categories: Technical, including the envelope of the building and the heating/ventilation/conditioning equipment, Environmental, covering aspects such as mobility, waste management, water and space within the block, and Services and common equipment, mainly providing common spaces and equipment to enhance quality of life and promote social ties within the city block.

A template was structured around seven sections: The “flow” section describes the technical flows to which an element is related. For instance, a heat pump produces heat and consumes electricity. The “space” section serves as enumerating constraints or properties of the space that is required for an element. Indeed, some elements require natural light or outside access, while other are better located in the basements. Similarly, the “equipment” section gives an overview of what is physically necessary to operate the element. It can include furniture, computers, washing machines, home cinema, etc. The two next sections “tasks” and “activities” relate to the humans actions required to make it work. The former enumerates the minimum set of activities that are absolutely necessary to have an element running, such as the cleaning of a common area or some accounting activities, while the latter gives a list of activities that can be grafted on the element, such as various courses or social activities. Although this list cannot be exhaustive, it is of the utmost importance as many of the enumerated items can be strong incentives for an SCB. Next, an “advantage” section gives indication of the type of benefits (environmental, economical, functional, social or related to energy) that can be provided by the element. A “scenario” section gives some indications of the elements that best work together either for effectiveness of the solution or for increasing quality of life within the SCB.

Once defined, the templates were filled in by specialists of the different disciplines. Over 50 elements were fully described and consolidated into a database for further processing. The advantages of creating a database are threefold: 1) it allows displaying the gathered information in various formats (paper, electronic) and with various levels of detail, 2) it enables online dynamic questionnaires where the sequence of choices can serve as indicator of preferences, 3) it allows filtering of elements based on various criteria (such as available space) or on preferred activities or competences available in the city block.

A third step of the elaboration of the catalogue was the initial identification of barriers to the SCB concept. They are diverse by nature: economic, city planning, architectural, technical, legal but also social and psychological. This initial list is to be updated during the qualitative interviews of the survey.

The fourth and final step consisted in an analysis of the relations between the elements. This was eased by the existence of the database which allows automatic generation of “technical scenarios” and the extraction of the “human scenarios”. The relations between the elements are represented by the organic Figure 1 below.
The distance between elements in these diagrams is inversely proportional to the number of existing links of a specific element. The colour of the links either represents heat, electricity and water flows or efficient coupling of the elements (functional or related to social practices). The centrality analysis carried out on these diagrams showed the strong interest to focus of photovoltaic panels and cogeneration with small heat networks as a starting point for the technical aspects. From the human viewpoint, centrality is less apparent, but different scenarios appear related to common space and infrastructure (guest room, shared office, multifunctional room) or to leisure (garden, vegetable garden).

City-block segmentation in Brussels

It is one thing to have a relatively complete catalogue of elements and another to adapt the offering to various city blocks of a town such as Brussels. Indeed, like most large cities in Europe, Brussels is characterized by its heterogeneity in terms of population and infrastructure environment and it was essential, for the sake of the survey, to take this into account at both levels:

- The infrastructure environment heterogeneity and its consequences on the type of renovation best suitable to the local environment considered.
- The population heterogeneity and its interests, understanding and acceptance of an SCB project.

As a consequence, the structure of the Brussels city was analysed in both directions (infrastructure and population) in order to dedicate the survey to each specific “population” and “environment”. The objective of the analysis was to produce a segmentation of the city based on a combination of both dimensions.

In first instance, all possible variables for both dimensions were listed during brainstorming sessions involving researchers from different disciplines (engineering, architecture, urban science, geography, economy, finance, sociology, psychology). It resulted into a list of 98 variables that have been grouped into six categories to
facilitate further in-detail analysis: Energy, Urbanism, Mobility, Environmental impact, Social impact and Financial.

The availability of data for each identified variable was then checked. There were variables for which there was no data easily available or accessible and for most other variables the main constraint was the level of detail and quality of the data available.

The main entity for an SCB project was the “city block” which was defined as a small area of the city that is surrounded by streets or other public domain limits (railways, rivers, etc.). There were only a few variables for which data existed at such level. Most of the data were available at larger levels such as the whole city, a municipality, a district or a so called “statistical entity” and at smaller levels such as a street, group of houses or one single home. The transposition of such data at city block level was achieved using powerful conversion tools run by researchers from the Brussels “Institute for Environmental Management and Land-use Planning”.

This resulted into a subset of 37 variables for which robust data were available at city block level for 3.600 of the city blocks of Brussels.

**Principal Component Analysis**

A large number of variables made it difficult to come to a segmentation of the Brussels region in terms of infrastructure and population criteria, so a Principal Component Analysis (PCA) was run. A PCA is a mathematical process using an orthogonal transformation to convert a set of observations of correlated variables into a new set of linearly uncorrelated variables called principal components.

<table>
<thead>
<tr>
<th>Total Variance Explained Component</th>
<th>Initial Eigenvalues</th>
<th>% of Variance</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>17.43</td>
<td>29.54</td>
<td>29.54</td>
</tr>
<tr>
<td>1</td>
<td>7.80</td>
<td>13.21</td>
<td>42.75</td>
</tr>
<tr>
<td>2</td>
<td>4.57</td>
<td>7.75</td>
<td>50.50</td>
</tr>
<tr>
<td>3</td>
<td>3.13</td>
<td>5.30</td>
<td>55.81</td>
</tr>
<tr>
<td>4</td>
<td>2.41</td>
<td>4.09</td>
<td>59.89</td>
</tr>
<tr>
<td>5</td>
<td>2.20</td>
<td>3.72</td>
<td>63.61</td>
</tr>
</tbody>
</table>

It resulted in having more than 63% of the overall variance of the source variables being explained by 6 principal components and the first two new variables resulting from the PCA covered 43% of the total variance.

**Building a topology of the Brussels Region**

The segmentation of the Brussels Region Based on those 6 principal components has been made possible through the use of a Ward hierarchical clustering criteria applied to our data set. It appeared that the loss of inter-group variance remained acceptable based on a 14 groups topology which was then chosen for conducting the SCB surveys.
A few observations can be made without going into a detailed view of the characteristics of each group:

- Each of the 14 groups is geographically homogeneous.
- There is a strong centric component of the city structure (linked to socio economic variables)
- There is a visible link between the main valley crossing the city from the North to the South and the topology structure (groups E and J corresponding to old and poor districts mixing housing and industry).

**Prioritizing the city block groups to be surveyed**

Since each of the 14 topology groups has unique population and infrastructure characteristics, it was decided to measure the level of acceptance of a SCB renovation at group level. Based on the per group values for a selected subset of the 37 original variables for which data was available, “deficit indicators” around environmental and social dimensions were built in order to prioritize the surveyed groups:

This made it possible to position each of the 14 topology groups on both axes (the size of each circle being proportional to the number of city blocks of the group):
Two criteria were established to determine priorities in terms of groups to be surveyed:

- The maximization of both deficits: 4 groups (I, E, G and H) being at the right side of the blue slash do maximize both deficits. Among those 4 groups, groups H and I were selected because they represent both extremes (I maximizing the social deficit and H the environmental deficit).
- The number of city blocks involved in each group: since groups A, K, L and M were close together in terms of deficits and represented 45% of all city blocks, the M group was chosen since it was the largest of all groups in the Brussels Region (18.8% of all city blocks).

Survey methodology and results

Three types of city blocks were chosen based on the above graph (Figure 2) in order to measure the level of acceptance of a SCB renovation by the concerned population:

- **Group H**: Older easy periphery (High-Net-Worth individuals), with very strong presence of luxury houses with 3-4 frontages and large gardens
- **Group I**: Old dense central districts, low socio-economic level, with a domination of old joint buildings, and remains of industrial function, lack of green space
- **Group M**: Apartments in joint buildings, above average social status, part of the first dense crown, Mid-20th century

A unique methodology was used in order to survey the three types of city blocks based on both a quantitative questionnaire and a qualitative survey (interviews):

Quantitative surveys included 41 questions covering all themes relevant to an SCB project (profile of the person answering the questionnaire, quality of current relationships with other inhabitants, type and importance of lived nuisances, interest for technologies related to energy, motivations and brakes to start an energy renovation project, desire to share activities in order to increase energy efficiency).
Qualitative questionnaires were used by graduate students as a guideline for interviewing inhabitants in order to go more in-depth in all possible directions and let them express their creativity. At this stage, our goal was not to assess the overall level of acceptance of an SCB project even within the three selected groups of city blocks but only to measure its perception by the population of some specific city blocks. Considering that the total number of city blocks per group varies from 176 (group H) to 677 (group M), it was not yet possible to draw conclusions based on a survey in a single city block per group. As a consequence, the survey will be continued in 2013 to broaden the target to other types of blocks.

The percentage of answered questionnaires varied considerably from one group to another:

<table>
<thead>
<tr>
<th>Group</th>
<th># Quest. distributed</th>
<th># answered quest.</th>
<th>Coverage</th>
<th>Total # of blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>92</td>
<td>3</td>
<td>8%</td>
<td>176</td>
</tr>
<tr>
<td>I</td>
<td>220</td>
<td>1</td>
<td>1%</td>
<td>396</td>
</tr>
<tr>
<td>M(1)</td>
<td>151</td>
<td>3</td>
<td>12%</td>
<td>677</td>
</tr>
<tr>
<td>M(2)</td>
<td>400</td>
<td>43</td>
<td>11%</td>
<td>677</td>
</tr>
</tbody>
</table>

In groups H and I, the very low participation to the survey was probably due to two reasons:
- The lack of financial motivation to participate to efforts in order to improve energy efficiency in Group H (while this is the group with the highest environmental deficit) probably combined with the above average age of the concerned population.
- The difficulty to communicate with the population in group I which was probably due to both a language barrier and the difficulty to understand some questions. Difficult working conditions also played a role in the lack of interest of the population while the potential impact of renovation in such a city block is considerable.

The survey coverage was better in group M which could probably be explained by the profile of inhabitants (above average social status) but as it remained at low level, we decided to test another set of three city blocks in the same M group (see M(2) in the above table) having as particularity of being part of a local Non-Profit Organization (NPO) active in the environment and in particular in energy savings. There was no positive impact of local relays such as this environmental NPO on the number of answers to the questionnaire although the number and motivation of participants during the local information sessions was higher.

**Preliminary survey results**

At this stage, group M is the only one from which relevant conclusions can be drawn from the received answers: 70 exploitable answers were gathered out of which 46 (66%) from paper questionnaires and the other 24 answers via online questionnaire. As most of the paper answers for the M2 group were provided during the information session organized via the local relay while answers from the M1 group were mainly provided online (89%), this seems to indicate a preference for the online version within the population when there is no external intervention.

**Quality of relationships between inhabitants**

In general, there are good relationships between inhabitants of the M city blocks with a difference between M(1) and M(2), the last one showing a somewhat better average level of relationship to be related to the presence of a local relay without being able to determine the cause and effect:
Nuisance sources and quality elements of the environment

Most respondents provided an answer to this question. Noise, lack of green space and parking were the most reported problems but as this is specific to each selected city block, no general conclusion may be drawn.

Intention to make use of new environmental technologies

Based on a list of proposed technologies, the percentage of positive answers indicating that the person has the intention to envisage a technology is globally at 22% with major variations between the elements:

The more complex the technology the less attractive it seems to be. This is probably largely due to a lack of understanding within the population, showing the possible impact of education and communication.

These results may further be differentiated between renters (17%) and owners (83%) of houses, showing less positive answers for renters (13% versus 25%). The impact of renting can be further illustrated when looking at the age of central boilers: the average age of boilers is 16.9 years for renters while it is only 12.4 years for owners showing the difficulty for renters to have their owners investing in new technologies while the impact of energy costs on the whole family budgets (2.523€ per year in average) is perceived as too high by a majority of respondents. On the other hand, there is no correlation between the intention to renovate and the level of the energy bill (correl =-0.01).

Attractiveness of new shared activities aiming at reducing the energy consumption

Next to the introduction of new technologies to reduce the energy bills and increase the share of renewable energies, the goal of the survey was to measure the attractiveness and degree of acceptance of new activities performed in common at the level of the city block.

The list of suggested activities has been made during large scale brain sessions involving participants from broad horizons and the responses are as follows:
The first observation from these answers is that there is a very low interest to share activities within the surveyed population. Only 15% of the 1,676 answers were positive, 26% “maybe”, 36% “no” and 23% not having an opinion. Such a low attractiveness of common activities is perhaps due to the above average socio-economic level of the population in the surveyed city blocks but on the other hand, it is also possible that their higher education level (18% having a PhD and 43% a master diploma) contributed positively to the answers due to their understanding of the positive energy impact of such shared activities. Therefore, our next short term objective will be to survey other city blocks representing different socio-economic categories of the population.

**Preliminary conclusions**

While the small scale of the administered survey makes it impossible to draw final conclusions about the acceptance level to such a SCB renovation project within the Brussels population, some first observations can be made:

- In general, people are heavily sensible to the quality of their environment and the reported nuisances match the importance criteria for such a quality environment.
- There is a low attractiveness of energy saving technologies within the population. A lack of understanding of technologies is reflected in the finding that the more complex an energy saving technology is, the less attractive the option is for survey respondents.
- Renting a house is a strong obstacle to envisaging renovation projects. Owners do favor their own houses for such projects.
- There is a very low interest within the surveyed population to share activities in order to improve the energy impact. Such lack of interest will have to be confirmed by new surveys in other categories of the Brussels population.

**Bibliography**

