D1.5

Coherent state-of-the-art design guidelines for energy-efficient healthcare districts

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STREAMER - Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems.
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Coherent state-of-the-art design guidelines for energy-efficient healthcare districts

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Colophon

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Abstract

The main objective of the STREAMER project is the development of design methodologies which will enable a 50% reduction in the amount of energy consumed by hospitals. These methodologies rely heavily on Building Information Modelling (BIM) and the availability of expert knowledge in a useable format in an early design phase.

In this Deliverable, an effort is made to identify, capture and structure this expert knowledge so it can be used by the design team in an early design phase, in both refurbishment and new build situations. This is referred to in the description of work as “the conversion of existing energy-efficient building guidelines into semantic rules for BIM”.

Five research fields of expert knowledge have been selected:

1. KPI’s; Including them in this task ensures a balanced approach between energy saving measures and a safe, user-friendly, and cost-effective environment.
2. Hospital questions; all four hospital partners of STREAMER have been asked to provide research questions (called “hospital questions”) that to them are important within the scope of STREAMER.
3. Labels; these provide a strong theoretical basis for enriching space-related elements in the BIM, such as rooms and functional areas, with knowledge.
4. Energy; this research field has been incorporated to split the main objective of the STREAMER project (energy reduction) into more specific aspects.
5. GIS/BIM; this essential part of the deliverable and is included in order to relate the other knowledge fields to individual neighbourhood and hospital components.

In total, 964 relations between topics within these five research fields have been described in a datasheet. These relationships and their descriptions are the basis for BIM design template development in D1.6 and will provide suggestions for the development of EeB solutions (WP2), KPI’s (WP3), knowledge retrieval techniques (WP4), parametric modelling techniques (WP5) and requirement models (WP6).

Publishable executive summary

The main objective of the STREAMER project is the development of design methodologies which will enable a 50% reduction in the amount of energy consumed by hospitals. These methodologies rely heavily on Building Information Modelling (BIM), the availability of expert knowledge in a useable format and energy consumption calculation, all in an early design phase.

Although energy performance calculations performed during the final design stages are complex because they take a lot of detailed information into consideration, it’s actually much harder to perform energy performance calculations in an early design stage. Reason behind this is that the person(s) performing the calculation in a final design stage will be provided with accurate and detailed input, which can be processed by software capable of processing this complex information. In an early design phase, the information is simply not present. Expert knowledge is needed to fill in these “information gaps” in order to perform any calculation (or: estimation) at all. To make matters even more complex, the energy efficiency should not conflict with a safe, user-friendly, and cost-effective environment.
To put it simply; it would be unacceptable to not place windows because glass is too thermally conductive, or to lower the air change rate in the operation rooms because it uses so much energy. To make the right choices in complex buildings like hospitals requires an extremely high level of expert knowledge in architecture, engineering and construction.

In this Deliverable, an effort is made to identify, capture and structure this expert knowledge so it can be used by the design team in an early design phase, in both refurbishment and new build situations. This is referred to in the description of work as “the conversion of existing energy-efficient building guidelines into semantic rules for BIM”.

The expert knowledge collected in this deliverable originates from five research fields:

1. KPI’s; in STREAMER deliverable 3.1, Key Performance Indicators (KPI´s) have been researched. Including them in this task ensures a balanced approach between energy saving measures and a safe, user-friendly, and cost-effective environment.
2. Hospital questions; The hospital questions hereafter listed have been provided by each hospital involved in STREAMER and address issues they directly experienced when designing, maintaining and managing their healthcare districts and buildings. The questions elaborated are of three different kinds; strategic, functional and environmental. These questions have been included in this deliverable to relate the developed theory to “the real world”.
3. Labels; the labels as developed in D1.1 provide a strong theoretical basis for enriching space-related elements in the BIM, such as rooms and functional areas, with knowledge. The labelling concept has been tested within STREAMER in WP7 and so far has proven useful in enriching the BIM with valuable STREAMER-related data. In this deliverable the list has been significantly expanded. The AOUC Careggi has been taken as example to test and validate the new labels and system.

4. Energy; The selection of energy aspects and instances has been done to split the main objective of the STREAMER project (energy reduction) into more specific aspects and allow relations to the other research fields within the scope of STREAMER.. A distinction in scale level has been made to allow accurate descriptions when describing relations with scale- dependent aspects, like BIM elements.
5. GIS/BIM; the four research fields mentioned above have to be related to geometrical representations of (existing or new) elements. Both GIS and BIM are databases containing these elements, so they have been combined in the same knowledge field. This research field contains elements on all scale levels as defined in STREAMER: neighbourhood/district, building, functional area, spatial unit/room and component.

To structure the data within this document, the information contained within the five research fields has been subdivided into "aspects", which in turn can contain multiple "instances". Two examples:

Research field: GIS/BIM
Aspect: room
Instance: patient room

Research field: energy
Aspect: ventilation (on building level)
Instance: natural ventilation

All this information has been captured in a datasheet. On the X- and Y-axes, the aspects and instances are listed and described. At the intersections of these rows and columns, a text has been provided to describe the relation. There are three different text options:

a) description of the relation

b) "no relation"

c) relation to be determined in STREAMER T (task number) + explanation

The sheet contains 1955 fields that have been provided with information.
991 fields (51%) are "no relation"
0 are relation to be determined in STREAMER WP1
29 are relation to be determined in STREAMER WP2
13 are relation to be determined in STREAMER WP3
0 are relation to be determined in STREAMER WP4
8 are relation to be determined in STREAMER WP5
0 are relation to be determined in STREAMER WP6
0 are relation to be determined in STREAMER WP7
914 fields (47%) are described relations

KNOWLEDGE FIELD				KPI	KPI	KPI	KPI
	ASPECT				Energy performance and efficiency	Financial analysis based in whole life costing	Quality of the environme and operational efficienc
		INSTANCE					
			DESCRIPTION	Key Performance Indicator			
Hospital Question			question relevant for hospital organizations within the scope of Streamer				
Hospital Question	Which aspects are related to the integration of the hospital into the surroundings?				Reduction of emission and potential distribution of surplus of energy production	Financial issues related to the distribution of surplus of energy production	Satisfaction of users' needs and improvement operational efficiency
Hospital Question	Which aspects are related to the integration of planting/nature?				no relation	no relation	Satisfaction of users' needs and improvement quality of environment
Hospital Question	Should we consider automated transport?		self-navigating vehicles / transport carts		no relation	relation to be determined in Streamer T3.3 (D3.6)	Improvement of the operational efficiency
Hospital Question	What should we consider to lower the total cost of ownership?				Evaluation of the energy performance and efficiency	Data related on the whole life costing gives information on the waste of money that could be avoided and savings that could be obtained	Improvement of the operational efficiency

Fig 1: A screenshot of the datasheet (as in the appendix).

An example:

One of the hospital questions is: ”Which systems can we implement to improve comfort conditions for patients in summer and winter?” Related aspects from the datasheet are: (descriptions of the relation are between brackets):

Labels:

- Indoor quality (Indoor quality requirements will set comfort conditions and will frame possibilities for improvement).
- HVAC and lighting (HVAC and lighting requirements will set comfort conditions and will frame possibilities for improvement).

Energy:

- Ventilation on room level (Ventilation system can improve comfort condition in the room).
- Lighting (Better lighting conditions improve comfort conditions all year long).

BIM:

- The PoR (Requirements related to patient comfort should be in the PoR).
- Building envelope (Building envelope properties are related to patient comfort (e.g. openable windows).

KPI:

- Financial analysis based on whole life costing (Financial sustainability of measures to improve comfort condition)

This information will help the stakeholders to understand which information and responsibilities are related to one specific aspect of the design, in this case a hospital question. Some conclusions that can be drawn from this example:

- At least two labels should be incorporated in the design.
- The MEP engineers should pay special attention to lighting and ventilation aspects.
- The recommendation for the hospital is to include requirements related to patient comfort in the PoR.
- The architect should pay special attention to the building envelope.

These relationships and their descriptions are the basis for BIM design template development in D1.6 and will provide suggestions for the development of EeB solutions (WP2), KPI's (WP3), knowledge retrieval techniques (WP4), parametric modelling techniques (WP5) and requirement models (WP6).

List of acronyms and abbreviations

BIM: Building Information Modelling

EeB: Energy-efficient Building

GIS: Geographic Information System

HVAC: Heating, Ventilation, Air Conditioning

KPI: Key Performance Indicator

MEP: Mechanical, Electrical, Plumbing technologies

PoR: Programme of Requirements

WPx: Work Package (no.)

Tx.x: Task (no.)

Dx.x: Deliverable (no.)

Label: property tag attached to spatial component

Research field: topic within STREAMER

Aspect: topic / item within a research field

Instance: subtopic / subitem of an aspect

Research field: GIS/BIM
Aspect : room
Instance: patient room

Definitions

“Semantics is the study of meaning. It focuses on the relation between signifiers, like words, phrases, signs, and symbols, and what they stand for, their denotation”. (Source: Wikipedia)
In the STREAMER context, examples of signifiers can be: a wall, a room, a KPI, the concept of natural ventilation etc.

Semantic (baseline) design model: a collection of design guidelines and the relationships between them.

Ssemantic rules for BIM: relationships between objects and/or information within the BIM environment.

Contents

1. Introduction

Connected information tells us more than stand-alone information. For example, within a multidisciplinary BIM, the amount of information exceeds the information contained in the individual aspect models. The connections, or relations, allow us to verify the quality of the individual models. A basic example of this verification is a clash control between the building services and structural BIMs. If there are no clashes, the individual models are correct. But we can only tell after the models have been put together and analyzed.

When we consider analysis of the BIM, validation based on geometrical properties as mentioned above is relatively straightforward.

It is more complicated when we want to know if the design, as represented by the BIM in an early design stage, is energy-efficient. Although energy performance calculations performed during the final design stages are complex because they take a lot of detailed information into consideration, it's actually much harder to perform energy performance calculations in an early design stage. Reason behind this is that the person(s) performing the calculation in a final design stage will be provided with accurate and detailed input, which can be processed by software capable of processing this complex information. In an early design phase, the information is simply not present. Expert knowledge is needed to fill in these "information gaps" in order to perform any calculation (or: estimation) at all. To make matters even more complex, the energy efficiency should not conflict with a safe, user-friendly, and cost-effective environment.
To put it simply; it would be unacceptable to not place windows because glass is too thermally conductive, or to lower the air change rate in the operation rooms because it uses so much energy. To make the right choices in complex buildings like hospitals requires an extremely high level of expert knowledge in architecture, engineering and construction.

In STREAMER, expert knowledge is captured and structured so it can be used in the BIM in an early design phase. The design will become more energy-efficient because the design team can make use of increased and improved analysis possibilities based on this knowledge. In the description of work this is referred to as "design methodology".

The question that is addressed in this deliverable is: which knowledge is relevant for this purpose, and how is it related to the BIM? The answer to this question is referred to in the description of work as "the conversion of existing energy-efficient building guidelines into semantic rules for BIM".

2. Framework

2.1 Research fields

A first step to answering the question mentioned in the introduction is to determine which research fields contain this desired knowledge. Five research fields have been selected:

1. KPI's; in STREAMER deliverable 3.1, Key Performance Indicators (KPI´s) have been researched. Including them in this task ensures a balanced approach between energy saving measures and a safe, user-friendly, and cost-effective environment.
2. Hospital questions; all four hospital partners of STREAMER are involved in this deliverable. They have been asked to provide research questions (called "hospital questions") that to them are important within the scope of STREAMER. These questions have been included in this deliverable to relate the developed theory to "the real world".
3. Labels; the labels as developed in D1.1 provide a strong theoretical basis for enriching space-related elements in the BIM, such as rooms and functional areas, with knowledge. The labeling concept has been tested within STREAMER in WP7 and has proven useful in enriching the BIM with valuable STREAMER-related data.
4. Energy; this research field has been incorporated to split the main objective of the STREAMER project (energy reduction) into more specific aspects.
5. GIS/BIM; the four research fields mentioned above have to be related to geometrical representations of (existing or new) elements. Both GIS and BIM are databases containing these elements, so they have been combined in the same knowledge field.

2.2 Scope

Scale level

This deliverable will cover all major scale levels defined in STREAMER; neighbourhood/district, building, functional area, spatial unit/room and component.

Existing and new buildings

Both retrofit and new build situations are incorporated in this deliverable.

2.3 Aspects and instances

To structure the data within the document, the information contained within the five research fields has been subdivided into "aspects", which in turn can contain multiple "instances". Two examples:

Research field: GIS/BIM
Aspect : room
Instance: patient room

Research field: energy
Aspect: ventilation (on building level)
Instance: natural ventilation

3. Information: research field content

3.1 GIS/BIM

A common definition of GIS:

A geographic information system, or GIS, is a computerized data management system used to capture, store, manage, retrieve, analyze, and display spatial information. A GIS differs from other graphics systems in several respects. First, data are georeferenced to the coordinates of a particular projection system. This allows precise placement of features on the earth's surface and maintains the spatial relationships between mapped features. As a result, commonly referenced data can be overlaid to determine relationships between data elements.

(http://nerrs.noaa.gov/doc/siteprofile/acebasin/html/gis_data/gisint2.htm)

A common definition of BIM:

Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder. (NBIMS[1]).

Almost all information in the BIM is attached to geometrical objects which are created using modelling software. These geometrical objects always contain some form of data (semantics). For example, a specific floor in a project has geometrical information (length, width, thickness, position) and identity data (so we know it's a floor). This identity data is created by the modelling tool. Even though the geometrical properties of a floor can be the same as a roof, they can be recognized by their identity data.

The objects can be enriched with more data. This is necessary for purposes of model analysis. There are several types of analysis, of which cost, structural and energy performance are most common. To be able to make an analysis, the objects in model should contain the correct information on the chosen topic. For example, a roof can contain information about costs, structural capacities and thermal insulation values. Further research on which information is important for BIM elements in a certain design phase is done in STREAMER task 5.1.

Some information is not created within the modelling environment. For example, data about the load-bearing capacities of the soil can be contained in a PDF file. It is neither possible nor desirable to insert this information to the data structure of the modelling software, or IFC file. However it is possible to attach

[1] National BIM Standard – United States. National Building Information Model Standard Project Committee, http://www.nationalbimstandard.org/faq.php#faq1 (accessed: 2014-01-20)

a hyperlink to the geometrical site component which links to the PDF file. The PDF file thus becomes integrated within the BIM.

Obviously, when building a database of aspects to be related to each other, one must anticipate to the establishment of relations by choosing aspects that are likely to allow relations. The choice of BIM elements should support the scope of design validation and the aspects related to energy, labels, KPI´s and hospital questions.

The list of BIM aspects (underlined) and instances (bullets) that have been selected for this deliverable[2]:

<u>Programme of requirements (PoR)</u>

The PoR can contain plain text or separate documents that are related to the building or building process in general. Several online tools provide a way to structure this information and make it easily accessible. Also, connections between data from the PoR and geometrical modelled objects can be made (these concepts are explained in STREAMER D4.3), effectively integrating the PoR with the BIM. The PoR can contain instances of:

- Project management (planning, tender procedure)
- Ambitions (includes information on sustainability-targets, costs)
- Comfort and safety demands (temperature, air quality, glare …)
- MEP components performance specification (mechanical, electrical, plumbing)
- Material performance specification (based on a coding structure such as NL-SfB)
- Project administration (includes minutes of meeting, planning)
- Standards/guidelines (includes links to building regulations)
- Context (includes maps, drawings of surroundings, existing situation)

Functional area- and room-based information can be attached and synchronized to matching elements in the model using specifically designed add-ons within the modelling software. It is important to realize that the requirements are not always met in the design (especially the room surface area, which depends largely on the architectural layout.).

- Room-related information (includes functional, technical, furniture and facility management brief)
- Functional area-related information (includes functional, technical, and facility management brief)

<u>GIS</u>

GIS data relevant for a project is obtained from external sources, rather than modelled or created specifically for the project. Information in the GIS includes:

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[2] An attempt has been made to provide universal naming of BIM elements. However, specific terminology is based on Autodesk Revit because this is currently the market leader in BIM modelling software for architects.

- Data related to soil composition (includes load-bearing properties, groundwater data, etc.)
- Data related to energy (includes energy profiles on building- and neighbourhood scale)
- Data related to buildings (includes information about other buildings, such as size, function, age, etc.)
- Data related to traffic (includes public transport, road capacities, noise pollution, etc.)

<u>Mass</u>

A mass can be used to model the expected size and volume of the project, and test how it fits on the plot and urban setting in an early design phase. Often the building context is also modelled as a collection of masses.

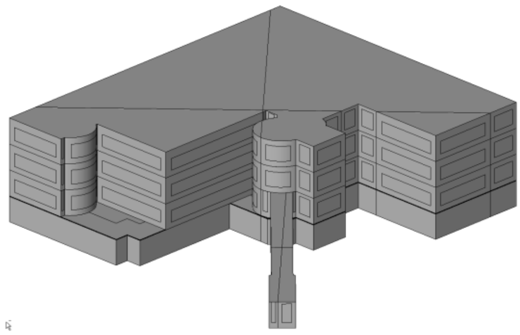

Fig. 2: Representation of the Rijnstate extension by a mass.

<u>Functional area</u>

A functional area is usually modelled as an "area". Although an area is a modelled component, it does not represent any geometrical element in the "real world". Areas can be connected to functional area-related information in the PoR.

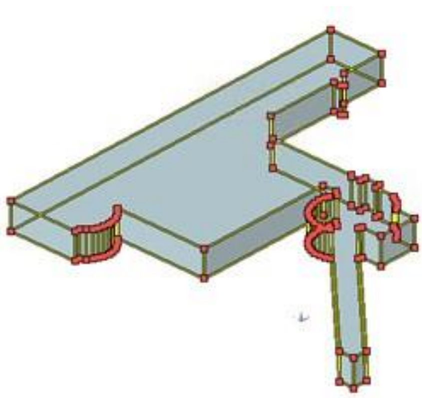

Fig. 3: representation of a functional area in the Rijnstate extension

All functional areas listed below have been selected and explained in D1.1. They have been added as instances.

Diagnostic treatment:

- Diagnostic imaging Nuclear medicine Radiotherapy
- Pre-hospitalization
- Endoscopy
- Blood sampling/testing
- Transfusion centre (blood bank)
- Rehabilitation
- Outpatient department

Ward:

- Intensive care ward
- High care ward Low
- care ward Medical
- day hospital
- Oncological day hospital
- Day surgery
- Maternity ward

Operating block:

- Operating theatres
- Interventional radiology

Accident and Emergency:

- Accident and Emergency (A&E)

General facilities:

- Medical testing laboratory
- Anatomical pathology laboratory
- Internal pharmacy
- Sterilization centre
- General storages
- Kitchen
- Canteen
- Medical archive
- Admission (reception, information, reservation)
- Garbage room and special materials disposal
- Mortuary
- Dressing rooms for staff
- Health physics
- Cleaning spaces

Public facilities:

- Central hall
- Cafeteria / restaurant
- Stores

Space-Unit / Room

"A room is a subdivision of space within a building model, based on elements such as walls, floors, roofs, and ceilings." (Autodesk[3]). Just like functional areas, rooms do not represent any geometrical element in the "real world". Rooms can be connected to room-related information in the PoR.

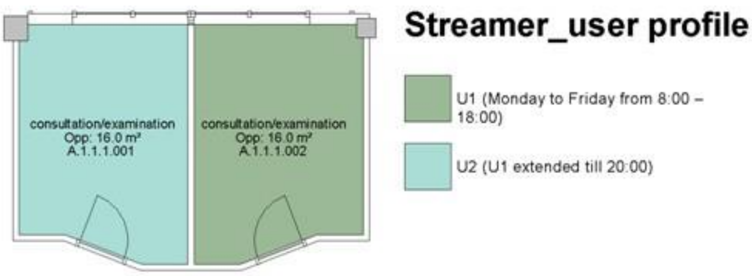

Fig. 4: Visualisation of room properties in a floor plan (Rijnstate extension)

All room instances listed below are based on a work-in-progress inventory of common room types and standards in Swedish hospitals, put together by 17 of 21 county councils. For the purpose of this deliverable, some changes to the list have been made. These changes include:

- Including important room types such as central hall
- Deleting rooms that are not relevant for the scope of STREAMER. For instance, office for 1 person, office for 2 persons and office for x persons have been combined into "office".

Selected room instances are:

- Air lock
- Ambulance hall
- Analysis room
- Ante-room
- Archives
- Basement
- Canteen
- Central hall
- Changing room (personnel)
- Conference room
- Conservation room
- Consultation + examination room
- Corridor

[3] Autodesk Revit 2015 help, http://help.autodesk.com/view/RVT/2015/ENU/?guid=GUID-DD74A51D-A0B0-4461-A4BA-0F9CCC191CDB (accessed: 2014-12-04)

- Day room
- Delivery room
- Disinfection room
- Dialysis
- Examination room
- CT Examination room
- ECG Examination room
- Endoscopy Examination room
- MR Examination room
- Triage Examination room
- Ultrasound Examination room
- X-ray Exercise rooms (revalidation)
- Group room
- Holding
- Kitchen
- Kitchen cleaning room
- Kitchenette
- Laboratory
- Laundry room
- Medication room
- Non-sterile washing room
- Nursing station
- Observation room
- Office
- On-call staff room
- Operation theatre
- Operation theatre, Hybrid
- Patient room
- Patient room (birth suite)
- Patient room (day hospital)
- Patient room (Intensive care)
- Personnel room
- Pharmacy
- Photocopier room
- Prayer room
- Preparation room
- Radiotherapy
- Reception
- Recovery room
- Recycling room

- Relatives room
- Resting room Patient
- Resting room Personnel
- Resuscitation/Children's ER
- Sanitation room
- Shower
- Shower for disabled people
- Sterile store, Infection control
- Store room
- Technical room
- Toilet
- Toilet for disabled people
- Trauma room
- Treatment room ER
- Unpacking room
- Waiting room

Outer building shell

The outside shell of a building contains the thermal envelope. From the energy perspective, its main function is to act as a buffer between the inside and outside climate. In the modelling environment, the thermal envelope contains the following instances:

- Exterior wall (structural wall layer not included)
- Window (window and frame)
- Curtain wall (window and frame)
- Roof (structural roof layer not included)
- Lowest insulated floor (structural floor layer not included)
- Door (to outside)
- Sun shading

Although it is possible to attach very detailed information to these elements, not all properties are included when exporting to IFC. A detailed example of information transfer included in a wall is provided in STREAMER deliverable 5.1.

Structural elements

Load-bearing elements are usually modelled by the structural engineer in a structural BIM. For the design process, the most influential instances in the model are:

- Structural column
- Structural wall
- Bracing
- Structural roof
- Structural floor

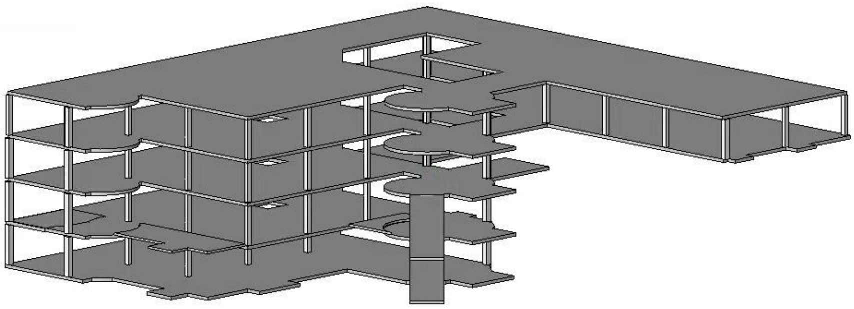

Fig.5: Structural model of the RIjnstate extension

<u>Building services</u>

Building services elements are usually modelled by the MEP engineer in a MEP BIM. For the design process, the most influential instances in the model are:

- Building management system
- HVAC zone
- Windmill
- Solar thermal panel
- PV panel
- Underground thermal storage
- Shaft opening
- Radiator
- Active ceiling
- Thermal active concrete floor
- Air conditioning unit
- Powerplant
- Boilerplant
- Sewage treatment recovery system
- Extended energy supply
- Chiller
- Air handling unit
- Pump
- Sprinkler installation
- Elevator
- Personal climate control (heating, cooling, ventilation)
- Vent (mechanical)
- Vent (natural)
- Plumbing fixture
- Lighting device
- Lighting fixture
- Electrical fixture

- Pipe
- Duct

User equipment

Non-medial user equipment such as computers, coffee machine, etc. can be modelled within the interior or architectural model. User equipment consumes a significant amount of energy, which is the reason it is incorporated in the scope of this deliverable.

Medical equipment

Specifications of medical equipment can have a significant impact on the design of medical-intensive areas of a hospital. For example, the size of medical imaging rooms is determined by the size of the medical imaging equipment.

Interior finishes

These relatively thin layers (finishes on walls, ceilings, floors) within the architectural model have a considerable impact on building and maintenance costs, people-friendliness and energy performance of a building.

3.2 KPIs

The KPIs for STREAMER have been developed as part of research in Work Package 3, and the results are presented in Deliverable D3.1 (publicly accessible).

The KPIs addressing Energy Performance and Efficiency use a “Layers” approach which considers that an acute hospital will consist of four definable usage types:

- Hotfloor
- Hotel
- Office
- Industry

They are used to identify the occupant usage characteristics which can, with the aid of a thermal model, help us understand the energy that can be used in each layer. An initial energy target can then be applied to each layer to enable the design process to progress within the parameters of the energy target. The areas of each layer combined with the energy modelled through the design process will offer the user the total theoretical energy use for the building.

The STREAMER KPIs on Energy Performance and Efficiency are:

1. Reduction of primary energy and carbon emission
2. Energy and carbon targets within country regulations
3. Energy and carbon targets within EU regulations
4. Energy and carbon targets developed as industry benchmarks
5. Energy and carbon targets developed through international best practice
6. Passive system integration

7. Active system integration
8. Use of renewable energy sources and technologies
9. Resilience risk (considered and managed)

When the energy model, energy target, building age and climate differences are taken into account we could consider the following matrix as a preliminary example of the manner in which the data may be represented for each project option.

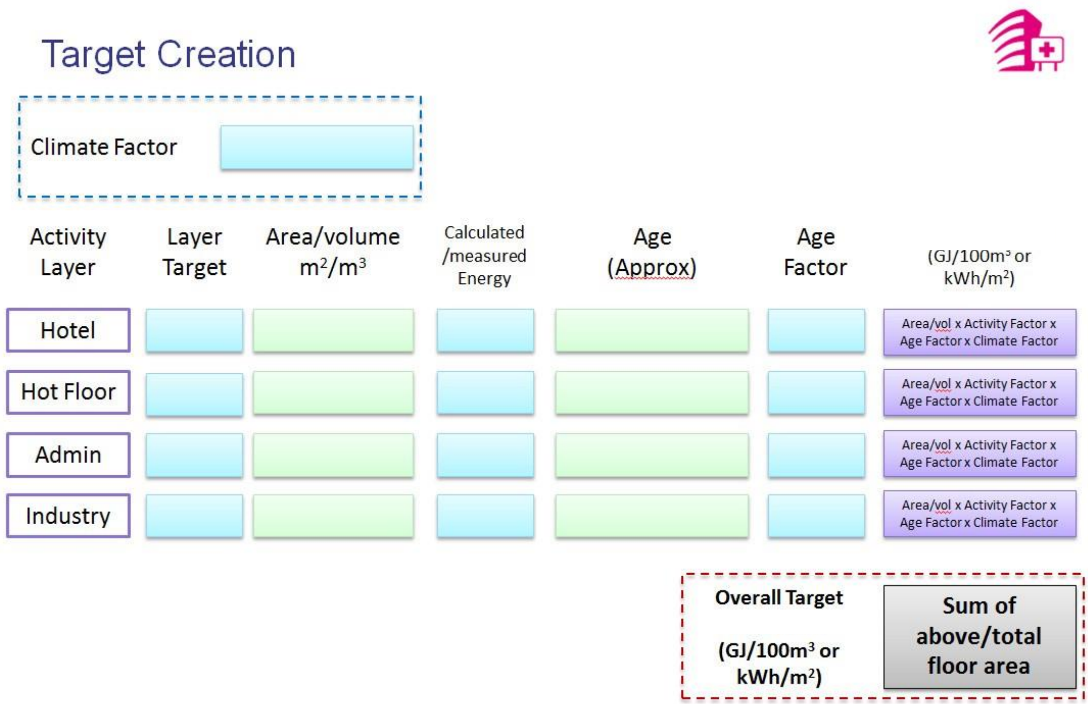

Fig. 6: template matrix for determining energy consumption on building level

It would be easy to develop KPIs that focused only on an energy target and compare the options against the quoted target. However, we have applied a more balanced approach to our process, not least of all because the selection of optimum solutions now more than ever depends on extremely complex multi-faceted/multi-discipline decision making processes. The simple intervention that makes significant change that is satisfactory to all stakeholders no longer exists.

The KPIs selected for STREAMER involve: 1) the efficient use of energy through an energy targeted approach; 2) the capital and operational costs through a whole life cycle cost; and 3) the development of the highest quality of environment and operational effectiveness through the development of a therapeutic environment. By considering these 3 types of KPIs, we believe that significant lower energy and higher quality environments will be achieved within the acute healthcare district/campus site.

3.3 Hospital questions

The hospital questions hereafter listed have been provided by each hospital involved in STREAMER and address issues they directly experienced when designing, maintaining or managing their healthcare districts and buildings. The questions elaborated are of three different kinds. Therefore, all the questions have been clustered according to the kind they belong to.

A first cluster of questions includes all the design considerations of strategic nature. Indeed, these questions aim to identify a strategy in order to solve issues at the level of the whole district in terms of operational efficiency and energy performance.

A second cluster of questions includes all the design considerations of functional nature. These questions aims to solve issues related to the lay-out of buildings in terms of distribution, accessibility, circulation, quality and use of spaces.

Last but not least, a third cluster of questions includes all the design considerations to be made from the environment perspective. The questions relate to the energy efficiency and to the requirements that guarantee the comfort conditions of spaces, thus heating/cooling, acoustic, lighting and ventilation systems.

The complete list of the hospital questions elaborated by the four hospitals (TRF, RNS, AOC, APH):

1. Strategy:
    - Which aspects are related to the integration of the hospital into the surroundings?
    - Which aspects are related to the integration of planting/nature?
    - Should we consider automated transport?
    - What should we consider to lower the total cost of ownership?
    - Should we build new or refurbish?
    - Should industrial services be outsourced?
    - Which energy saving measures can be taken when upgrading MEP/technical solutions?
    - Can we use part of the affected area during refurbishment process?
    - Which energy saving measures can be taken when renovating the building envelope?
    - Which connections to the existing infrastructure do our technical systems require?

2. Layout:
    - How to humanize the medical units so we can meet the expectations of the patients and their families?
    - How can we determine the optimum room configuration within a department?
    - How can we determine the optimum functional area configuration within a building? Are the building and its systems flexible?
    - Which distribution system layout will be most energy-efficient?
    - What should be considered to manage logistics/patients/personnel flows (inside and outside)?
    - Which factors contribute to improved security in a hospital which is per definition public?
    - Can we change 2-person to 1-person rooms?

3. Environment:
    - What are the options when considering renewable energy systems?
    - How to manage hygiene and safety rules?
    - Which systems can we implement to improve comfort conditions for patients in summer and winter?

- What is the optimal building orientation from the energy point of view?
- What will be the energy consumption of the new building?
- What is the availability of the primary energy sources and capacity?
- What should be the thermal performance of the building envelope?
- Are there spaces with comfort requirements?
- Do we want natural ventilation?
- Which energy performance level should be prescribed?
- Which systems can we implement to monitor the energy consumption?

As already stated, all these questions have been elaborated starting from the specific issues each hospital has to face or the requirements they experienced. In order to provide a framework to better understand the role and purpose of the hospital questions, a short text has been developed by each hospital regarding the considerations that lies behind the elaboration of the questions.

3.3.1 TRF (United Kingdom)

When analyzing the options available to TRF for renewable energy, several methods were considered. Solar PV was most noteworthy but the long payback period did not make it a viable option. Wind turbines are not suitable for this site due to the large amount of trees in the vicinity. Bio mass boilers were another option considered but due to the layout of the site and the concentration of services and buildings around the boiler houses, it was felt that it would not be practical or cost effective to store bio mass pellets remotely and discharge them to a boiler several hundred yards away. It would also involve costly alterations to accommodate a bio mass boiler into the existing heating infrastructure.

The main focus of this project for TRF is a retrofit solution for an existing building (or parts thereof) so the emphasis has not been directed to renewable energy options.

If TRT were to design and build a new healthcare premise then everything related to renewable supplies would be included at the design stage, eg Solar PV, Solar Thermal, etc., but finances dictate the investment for an existing building refurbishment.

TRF were involved in a project several years ago where a refurbishment would revolve around the design and build being devolved into a “pod” design, where as much as possible of the room / ward / bay would be constructed into kit form off-site, and the off-site works would greatly reduce the on-site building works, lessening the number of trades on-site, the length of the building works and having the desired effect of reducing Health & Safety and hygiene issues.

TRF is currently undertaking an upgrade of heating controls, rolling out a programme of automatic local adjustment in ward bays / cubicles etc. The environment will be greatly improved for both staff and patients and energy savings will also be made due to achieving optimum heating and cooling levels.

Rotherham Hospital is designed in such a way as to maximize as much natural daylight as possible, but obviously it is not possible to have all areas benefiting from the orientation. Typically, wards are set up in a south to south easterly or south to south westerly facing manner as far as possible.

TRF is in the process of installing electricity monitoring of both the areas selected for this project down to circuit level. This will give an accurate data set going forward. Previously these areas had not been metered.

Rotherham Hospital utilizes a CHP that when running at its optimum efficiency will generate approximately 66% of the site base load. The remainder is purchased from the national grid network and the available capacity is currently 2155 kVA.

The refurbishment of any part of the building should meet with the requirements of BREEAM (The Building Research Establishment Environmental Assessment Methodology) and aspire to achieve a rating of Excellent or Outstanding. Certain areas (mostly clinical) where patients change or lay / sit in bed wear or treatment robes require more definitive temperature levels. Other examples are Special Care Baby Unit (SCBU) and Theatres. It is the intention to use natural ventilation or free cooling wherever practicable; however this should never be at the expense of environmental performance.

In the UK energy performance of a building can be assessed by the scoring in a Display Energy Certificate (DEC), where real energy data is fed into a software programme that will grade the building against a benchmark score of a “typical” similar type building.

Local sub metering, preferably web based or integrated on to the BMS, would be the desired option. This would provide the ability to analyze a location / area and drill down to establish the cause of any major variations, e.g. extended opening hours, installation of new energy hungry equipment etc.

3.3.2 RNS (Netherlands)

The Rijnstate Hospital is situated in a complex environment: close to the neighborhood and the housing around it. Rijnstate has developed a masterplan in which a first step is to add 10.000 m2 to the existing facility, while at the same time substantially cutting emissions of greenhouse gases. Also, a renovation of existing MEP systems is prepared and some of the high care departments such as the intensive care and the operating theatres will be renovated in the near future. Creating added value for the workers, the visitors and the neighbourhood in such a complex environment is a constant challenge.

Rijnstate is looking forward to implementing innovative design solutions which will ensure a balance between an improvement in the quality of healthcare, the processes behind the primary process and energy reduction. The extension and part of the existing hospital have been modelled in a BIM specifically made to test and evaluate Streamer knowledge and methodologies. The BIM is enriched with data from the programme of requirements, which includes the labelling system as explained in this deliverable. The research questions provided by Rijnstate therefore have a strong focus on the possibilities of spatial layout configuration, based on information from the PoR.

3.3.3 AOC (Italy)

The questions that Careggi hospital takes into account are the ones deriving from both the analysis and application of the “New Careggi Plan”, the instrument that has been defining all the interventions to be made in the district since 2000. This plan was conceived in order to, on one hand, prevent the surrounding unique landscape to be destroyed and, on the other hand, to modify the functional model in order to tackle the lack of operational efficiency, difficulty of management and bad logistic organization within the whole system.

Therefore, the main purposes of the “New Careggi plan” were:

- renovation of the buildings,
- reorganization of the transportation network inside and outside the hospital area,

- concentration of functions (care, teaching and management) to reduce the number of buildings and merge university teaching and research activities with healthcare activities.

Today, Careggi is facing some important problems that still need to be solved, which led to formulate design considerations within the scope of D1.5 on three different levels.

First of all, the "New Careggi Plan" has so far entailed the demolition of high numbers of buildings to allow the realization of new buildings well-integrated with the environment and landscape and more efficient from the energetic and operational perspective. Today, Careggi is looking for an intervention strategy to be adopted regarding some of the buildings that needs to be either refurbished or demolished (e.g. San Luca Vecchio). For this purpose, many aspects require to be analyzed in order to provide the better solution: advantages of improving the MEP solutions, quality of the environment (safety, hygiene, etc.), level of operational efficiency within the buildings (e.g. logistics, flow), possibility to adapt the layout to the new demand, etc..

In addition to this issue, Careggi hospital continuously has to face the problem of communication and transport within the complexity of the district. For this reason, the aspects and circumstances that entail problems of inefficiency have to be analyzed and tackled; and design considerations about the inside and outside flows of patients and staff, logistics management, position of facilities and services and transports' organization always have to be made.

Last but not least, Careggi is facing today's problems concerning the operation and possible use of the trigeneration plant, which produces at the same time electricity, heat and water for conditioning with a minimum degree of energy use and environmental impact. The plant, which has been in operation since a few months, foresees the possibility to sell the energy to the surrounding facilities outside the Careggi hospital. Of course, this possibility requires an attentive analysis of related aspects in order to be realized which lead to questions regarding the integration with the surroundings, the LCC, the total cost of ownership, etc.

3.3.4 APHP (France)

The question of integrating a healthcare building in its immediate surrounding is an important issue when building a new site or when refurbishing an old one. Consequently, a lot of aspects have to be carefully considered:

- Analysis of the urban context for obtaining the building permit; especially regarding the potential contestation and opposition of the residents. That is the reason why the integration into the landscape is very important: the building has to be visually integrated, that is to say it must not differentiate from the other buildings of the neighbourhood, especially in an urban context (material, colour, architectural style, etc.). Besides, it has to integrate, as far as possible, green areas in order to improve the patients' comfort and quality of life. Discussions with the project's stakeholders and particularly with the state-appointed architect responsible for the protection of monuments are then necessary to clearly identify the main aspects that have to be tackled to ensure an appropriate integration and avoid strong opposition of the project.
- Accessibility of the construction site for the trucks, workers, etc that has to be quite easy.
- Connectivity to transport: the building has to be easily reachable by different means of transport and this aspect covers at the same the connectivity to public transport (are there any bus, train,

subway or tramway lines which serve the hospital, do they often run and how late do they run, are there within a walking distance, etc.) and the connectivity for cars (are there highways or just simple road nearby, are they one-way or two-way streets, how many parking spaces will be necessary, is there any risk of traffic jam outside and inside the hospital that could lead to the blocking of an ambulance for example, etc.).

- Accessibility of the building: all the facilities have to be easily available to all the hospital's users (patients, families, staff and suppliers without creating disturbances for the hospital functioning regarding these different flows) and particularly to persons with limited mobility, for visually impaired persons, etc. and also for the different fire and rescue services.
- Connection with energy systems: the proximity of existing energy systems (urban heating or cooling systems for example) can facilitate the integration of a building. As a matter of fact, if the new building is far from any source of energy, the related costs to connect the site can be very important. Moreover, the way the energy is produced (renewable or fossil energy) also has to be taken into account.

3.4 Energy

The selection of energy aspects and instances has been done to split the main objective of the STREAMER project (energy reduction) into more specific aspects and allow relations to the other research fields within the scope of STREAMER.. A distinction in scale level has been made to allow accurate descriptions when describing relations with scale-dependent aspects, like BIM elements.

The list of energy aspects (underlined) and instances (bullets) that have been selected for this deliverable:

<u>Ventilation (on room-level)</u>

- Natural
- Mechanical
- Personal
- Special
- Individual regulation
- Local regulation

<u>Ventilation (on building-level)</u>

- Air preparation in AHU
- Air distribution

<u>Heating (on building / neighbourhood level)</u> Production

- Distribution
- Regulation
- Storage

<u>Heating (on one or more room-level)</u>

- Water system

- Air system
- Radiant
- Convective
- Local regulation

Cooling (on building / neighbourhood level)

- Production
- Distribution
- Regulation
- Storage

Cooling (on one or more room-level)

- Water system
- Air system
- Radiant
- Convective
- Local regulation

Lighting (on room-level)

- Incandescent
- Fluorescent
- LED
- Automatic control
- Manual control

Hot water Heating (on building / neighbourhood level)

- Production Renewable
- Distribution
- Storage
- Water treatment

Production

- Electricity
- Cooling
- Heating

Medical gases

Communication

Outside climate

- Heat
- Cold
- Wind
- Solar radiation

3.5 Labels

In STREAMER Deliverable 1.1 a set of parameters for labeling the lowest level of space unit has been proposed. This method introduces a set of codes and references that allows us to identify the spaces through the relations between spatial, functional and energy related features. The labels enable us to attach properties and characteristics to the different spaces and thus carry implicitly a lot of semantic information.

By adding this information through the labels it will be possible to, on one hand, optimize the (energy) performance of the buildings and, on the other hand, to understand the implication of design choices in an early stage.

The labelling method as developed aims to identify parameters and information and transfer these aspects into the semantic BIM model database. The main parameters and categories have been defined in the D1.1 report and were further analysed and optimized in D1.5 for the finalization of the semantic labelling system. As part of this deliverable the labelling system has been subject to an attentive assessment and improvement in order to achieve the implementation of a clear and complete "labels' matrix".

The labelling system here defined has been applied and tested on the AOUC Careggi in order to validate its efficiency. This exercise has proven to be crucial to highlight the potentials and advantages of the system, as well as the incoherencies and inconsistencies of it. The last part of the paragraph shows a brief exemplification of this application.

Furthermore, the labelling system will be tested in the Rijnstate Hospital for WP7. In WP7 RNS and DJG are creating the BIM model of the demonstration case and are including the information regarding the labels within it. This test will be crucial to validate the compatibility with the tool and to assess the accomplishment of useful results.

As stated the careful preparation of labels and the corresponding parameters provide the design with the necessary information at all levels and gives insight into opportunities for optimization and design implications. The first step of this preparation consisted of defining the labels and adding levels to the labels.

It can be assumed that the initial labels cover the optimal properties of the spatial units and that, for this reason, these labels should be assigned to spatial units when preparing the PoR, thus at an early stage of design.

Considering the wide range of possible labels that could provide the space with valuable information, a few criteria have been identified to define the list of labels. The labels finally selected must respond to the following requirements:

- It must be objectively measurable
- It has to have a relation with physical aspects of the space
- It has to have a relation with the use/function of the space
- It has to have a relation with energy

These criteria led to the removal of some of the labels from the list as defined in D1.1 as they do not respond to the criteria identified above. The removed labels indeed turned out to be ineffective for the purpose of the labelling system in the STREAMER project, focusing rather on performance optimization or analysis of the design choices. Among these were the labels "Flexibility of space" and "Routes". On the other hand, some other labels have been introduced as they are considered useful for the BIM database.

The remaining fifteen labels have been grouped into eight clusters. The way the labels are grouped depends on their scope and features:

- The cluster “Layering labels”. This cluster includes the “Bouwcollege layers” label, which defines the performance requirements for each typology of accommodation or building type. This label is crucial within the design process as it provides the information to assess the validity of the design solutions adopted (e.g. adjacency between different typology of accommodation, preliminary energy analysis, etc.).
- The cluster “Functional labels” includes the label “Connectivity, adjacency”. This label is an important design tool as it describes the rules of the relationship among different functions and space, which consequently give information to develop the functional layout of the healthcare building. Nevertheless, this label has critical aspects that should be assessed in order to be operative within the semantic BIM tool, as described in this chapter later on.
- The cluster “Operational/usage labels” includes all those labels which deals with the operational efficiency of spaces and functions. They operate as rules to be respected in order to guarantee the healthiness and safety of patients and staff, as well as to optimize the efficiency of the hospital in terms of use of space and energy. Among these are the labels “Hygienic class”, “Accessibility”, “User profile” and “Safety”.
- The cluster “Equipment labels” consist of the “Equipment label” which defines the level of equipment necessary within a space in order to allow a proper development of the activity related to the type of space. This label has implications on the energy use of the whole hospital, as , for instance, it defines for which spaces extra power is needed.
- The cluster “Technical/structural labels” involves the “Construction” label which has an important role during the design process, as it provides information for designing hospital spaces according to the most suitable constructive characteristics.
- The Cluster “Environmental labels” includes the labels “Indoor quality” and “HVAC and lighting”. These labels contain all the comfort requirements of a space or a function, which consequently define the preconditions for MEP solutions, which will directly affect the energy use of the building. Therefore these labels play a crucial role within the STREAMER scope, as they provide information on the energy consumption of spaces.
- The Cluster “Architectural labels” includes all those labels which have a relation with the geometry of buildings and their volumetric and architectural characteristics. Among these: “Layout”, “Compactness”, “Mass” and “Form typology”. The information provided by these labels appears to be relevant from the energy and the operational efficiency perspectives.
- The cluster “Specific labels”, which contains labels that are defined specifically for each healthcare organization. For instance the “Organization” label which describes the coding system applied by each hospital to classify spaces and function. An example is the classification of spaces created by AOUC Careggi according to the S.A.C.S system.

Within each label a number of "levels" can be defined. Using these labels and levels it should be possible to define most of the requirements related to a specific activity and related space. Considering the complexity of healthcare districts requirements, the labelling system is applicable to each of the three main scale levels that build up healthcare districts: buildings, functional areas and space units. Therefore the labelling system could provide each level with parameters and factors that would inform the semantic BIM model on spatial, functional and energy related features. Table 1 shows a complete list of the labels, the clusters they belong to and the levels that build up the label.

LABELS CLUSTER	LABEL	LABELS'S DEFINITION	LEVELS	DESCRIPTION OF THE LEVEL
Layering labels	Bouwcollege layers	This label has a relation with the typology of functions and the requirements related	HF	Hot floor layer: capital intensive high-tech functions that are unique to the hospital
			H	Hotel layer: Patient accommodations
			O	Outpatient units, accounting, management and training functions
			I	Industry layer: laboratories, kitchen, etc.
Functional labels	Connectivity / adjacency	This label has a relation with the distance between functions and the spatial/functional relationship required between activities	CA1	not necessary
			CA2	strong functional connection between activities
			CA3	strong spatial connection with another activities required
			CA4	emergency connection with other activities
Operational/ Usage labels	Hygienic class	This label has a relation with amount of ventilation, air tightness, cleaning, materials necessary to meet the hygienic conditions requirements	H1	hygienic requirements related to reception activities
			H2	hygienic requirements related to office activities
			H3	hygienic requirements related to medical examination and treatment activities
			H4	hygienic requirements related to surgical activities
			H5	hygienic requirements related to laboratory activities
	Accessibility	This label has a relation with the position inside the hospital, safety/protective/security device	A1	public
			A2	accessible to patients, staff and visitors
			A3	accessible to patients and staff
			A4	accessible to staff
			A5	accessible only to specific staff members
	User profile	This label has a relation	U1	Monday to Friday 08:00 - 18:00

		with the usage time of spaces and the operating hours	U2	U1 extended till 20:00
			U3	U1 with emergency function outside timetable
			U4	24*7
	Safety	This label has a relation with the expedients necessary to assure the safety of people in relation to the activities/functions developed	S1	ordinary safety expedients
			S2	extra-ordinary safety expedients
			S3	supervisory control expedients
			S4	dressing up expedient
Equipment labels	Equipment	This label has a relation with the type of function, high electric power needed, medical gasses, ICT data points	EQ1	office
			EQ2	office+ medical gases
			EQ3	Office + extra electric power
			EQ4	Office + extra ICT data points
			EQ5	medical gases + extra electric power + extra ICT data points
			EQ6	high electrical safety
			EQ7	special equipment
Technical/ Structural labels	Construction	This label has a relation with floor strength, shielding against radiation, floor height, air tightness	C1	office requirements
			C2	Office + extra floor strength
			C3	office + extra floor height
			C4	office + extra floor strength and height
			C5	accessibility from outside with heavy load
			C6	shielding against radiation
			C7	high level of tightness
Environmental labels	Indoor Quality	This label has a relation with the needs for daylight, view outside and natural ventilation	IQ1	daylight
			IQ2	daylight and view out
			IQ3	daylight, view outside and mechanical ventilation
			IQ4	daylight and mechanical ventilation
			IQ5	mechanical ventilation
	HVAC and lighting	This label has a relation with the thermal, acoustic, lighting, ventilation, etc.	HL1	office and laboratory activities
			HL2	special laboratory activities

		requirements		
			HL3	medical examination and treatment activities
			HL4	surgical activities
Architectural labels	Layout	This label has a relation with the depth of the plan configuration	L1	deep plan configuration
			L2	narrow plan configuration
	Compactness	This label has a relation with the geometry of the building	CO1	high level of compactness
			CO2	low level of compactness
	Mass	This label has a relation with the property of the mass in terms of percentage of glazing and walls	M1	high % glazing
			M2	balance between walls and glazing
			M3	low % of glazing
	Form typology	This label has a relation with the possible arrangements of healthcare districts	FT1	Linked pavilion or finger plan
			FT2	Low-rise multi-courtyard or checkerboard
			FT3	Monoblock
			FT4	Podium with one or more tower
			FT5	Street
			FT6	Atrium/Galleria
			FT7	Unbundled
			FT8	Campus
			FT9	Layered
Specific labels	Organization	This label has a relation with the specific organization which each healthcare district classifies activities, spaces and functions with (e.g. S.A.C.S in Careggi healthcare district)	code	organization coding system

Table 1

While developing the matrix above, it became clear that the labels could be divided into two different groups: labels that require a “check” and labels that require a “number”. The first kind includes labels which inform the space with a property, a characteristic. For instance the label “User profile” which does not require the definition of a parameter value as it operates as sticker with information regarding the space. Labels of this kind are: Bouwcollege layers, Accessibility, User profile, Layout, Form typology, Organization. This in contrast to the second kind of labels that inform the space with a specific value, a parameter. If we consider the label “Hygenic class”, for instance, it entails the definition of a value to each level of the label. Among this kind of labels: Connection and Adjacency, Hygienic class, Safety, Equipment, Construction, Indoor Quality, HVAC and lighting and Compactness and Mass.

D1.6 will deal with the specific information that build up each level of a label. For the labels of the first kind, it will define the meaning, requirements and the implication of each property, while for the labels of the second kind it will provide the values to be considered as "standards" to be met. The information generated will then be assessed while validating the design choices through the design configurator.

Despite the different nature of these groups of labels, mostly all of them are structured and developed according to the same structure. All the levels within those labels are defined as "scores". This means, on the one hand, that the choice of a level is unambiguous and the assignment of multiple levels within one label to the same spatial unit is not allowed, and, on the other hand, that the levels are displayed on a scale of increasing (or decreasing) values, rather "scores".

At the moment, there is one label in particular for which the rules as described above are not valid. This label is "Connection and adjacency". This label includes different levels that do not exclude each other. It is highly possible that one space could be linked to more than one level of this label. For instance, a functional area or a space requires an emergency connection with a specific activity, but also a functional connection with another at the same time.

The question at this point is whether the BIM database could support the possibility of applying multiple levels within the same label. Further steps within the research should confirm the validity of this type of label by test and confirm whether the multiple levels are applicable in the semantic BIM model or not.

Connectivity / adjacency	This label has a relation with the distance between functions and the spatial/functional relationship required between activities	CA1	not necessary
		CA2	strong functional connection between activities
		CA3	strong spatial connection with another activities required
		CA4	emergency connection with other activities

Table 2: example of label that entails multiple choices

Another important observation is the fact that the label "Connection and adjacency" as formulated in table 2 can only work as a requirement if it is expressed in relation to another room or functional area. But this kind of relation within a label cannot be tested in a design validator. The same consideration applies to all the architectural labels (table 3) which cannot be tested the same way as the other labels, but still provide useful information regarding the design and the energy use of a building. In addition, these architectural labels all act on the building level, while the other labels could be applied to space units and functional areas. The latter could probably be assigned when preparing the PoR, while there is probably no need to have an architectural design at that stage.

According to this, it is important to establish the suitability of this group of labels.

Architectural labels	Layout	This label has a relation with the thickness of the plan configuration (??)	L1	deep plan configuration
			L2	narrow plan configuration
	Compactness	This label has a relation with the geometry of the building	CO1	high level of compactness
			CO2	low level of compactness
	Mass	This label has a relation with the property of the mass in terms of percentage of glazing and walls	M1	high % glazing
			M2	balance between walls and glazing
			M3	low % of glazing
	Form typology	This label has a relation with the possible arrangements of healthcare districts	FT1	Linked pavilion or finger plan
			FT2	Low-rise multi-courtyard or checkerboard
			FT3	Monoblock
			FT4	Podium with one or more tower
			FT5	Street
			FT6	Atrium/Galleria
			FT7	Unbundled
			FT8	Campus
			FT9	Layered

Table 3: example of label that express a requirement but cannot be tested in a design validator

After defining all the labels according to their levels, the elaboration of the labelling system focused on the definition of the relationship between the labels and the different scale levels (building, functional area, space units). The matrix in Table 4 shows which label could be applied at which level and how.

LABELS CLUSTER	LABEL	APPLICATION OF THE LABELTO THE SCALE LEVELS		
		Building	Functional area	Space units
Layering labels	Bouwcollege layers	X	X	X
Functional labels	Connectivity / adjacency		X	X
Operational/Usage labels	Hygienic class			X
	Accessibility		X	X

	User profile	X	X	
	Safety			X
Equipment labels	Equipment			X
Technical/Structural labels	Construction			X
Environmental labels	Indoor Quality			X
	HVAC and lighting			X
Architectural labels	Layout	X		
	Compactness	X		
	Mass	X		
	Form typology	X		
Specific labels	Organization	X	X	X

Table 4: application of the labelling system to the scale level

The black boxes displayed in the matrix explain the suitability of the labels to the scale levels. It does not mean that it is not possible to define the label-level at the scale level highlighted in black, but rather that according to the intended STREAMER approach, we try to define the scale level for which it is most logical to apply the label.

Indeed, it is possible to define some labels at the scale levels for which the matrix displays a black box through a “transferring properties” effect. This effect will be explained hereafter.

It is possible that in some cases multiple spaces with different label-properties will be concentrated in one single functional area or building. When this occurs there could be the effect of transferring properties of the predominant label to (all) other space units. This effect will be explained by a fictitious label “Ceiling height”. We could concentrate space units with different label-properties for ceiling height into one functional area: a single floor with rooms that require at least a 2,5 m high ceiling together with rooms that require a ceiling height of 3,5 m. This will often lead to constructing the building according to the predominant requirements: in this case the building area will be likely to be constructed with a ceiling height of 3,5 m. The effect of replacing the original optimal parameter of some of the rooms (a ceiling height of 2,5 m) with the inherited parameter (a ceiling height of 3,5 m) tells us something about the implications of this design choice on the single space units.

This means that when a large number of space units within a functional area (or functional areas within the building) is characterized by the same label’s parameter (most of the spatial units have the same label-level) or when a space unit (or functional area) has a predominant requirement, a process of “inheriting properties” could take place, through which the assignment of the label is homogenized to all the space units within a functional area (or a functional area within the building). According to this method, it is implicit that some labels are expected to be directly assigned, while others are supposed to be defined by the "inheriting properties" process.

The Bouwcollege layers, for instance, seem to be applicable at all scale-levels. But this does not necessarily mean that the spatial units have the same layer label for a certain function at each scale level. An office room will most likely have an office label at the space unit level, but when realised in a hot-floor functional area (like an office room in the operating department) it will probably 'inherit' the hot floor characteristics. Another example: the essence of a delivery ward is a hotel-function and can best be combined with other functions fitted in a hotel-like building. But when, for instance, from a process-view is decided to place the delivery ward as close to the operating room as possible, and as a result of that decision the delivery ward is placed on the same floor in the same building as the operating room, it is more likely to have hot-floor characteristics than hotel characteristics.

Of course, considering the fact that the original label reflects the optimal situation for a space, a functional area or a building, the inheriting properties process determines a deviation from the optimal situation. Therefore, in order to calculate this deviation, judge the effects of the chosen design and test alternatives, it is crucial to preserve information of its original properties.

As stated, the AOUC Careggi has been taken as example to test and validate the labelling system as described in this chapter. Here follows an exemplification of the labels assignment to one building, San Luca Building C ("San Luca nuovo") and a functional area and the spatial units within that building. The example traces the breakdown chosen in D1.1 to describe the STREAMER approach. The following table has also been used in D7.5, where it is more elaborately described.

LABELS CLUSTER	LABEL	APPLICATION OF THE LABELTO THE SCALE LEVELS		
		Building	Functional area	Space units
		SAN LUCA NUOVO	OUTPATIENT CLINIC	ERGOMETRICS AREA
Layering labels	Bouwcollege layers	Hot floor (HF)	Office (O)	Office (O)
Functional labels	Connectivity / adjacency		CA2	CA3
Operational/Usage labels	Hygienic class			H3
	Accessibility		A2	A3
	User profile	U4	U1	
	Safety			S1
Equipment labels	Equipment			E4
Technical/Structural labels	Construction			C1
Environmental	Indoor Quality			IQ3

labels	HVAC and lighting			HL3
Architectural labels	Layout	L2		
	Compactness	CO1		
	Mass	M2		
	Form typology	FT3		
Specific labels	Organization	16_C	Chest physiopathology outpatients	16_C_077

Table 5: Labelling system applied to Careggi

According to the nature of this deliverable, which is a guideline, the idea is to keep the matrix as it has been defined so far, including all the labels listed. In the near future, the task would be to define the method to enrich the system through the use of semantic rules within the tool. This method would allow testing the critical aspects of the labelling system here highlighted. This work should determine whether some of the labels are not compatible with the BIM model or not necessary for its objectives.

4. Knowledge: connecting the aspects

The relations between aspects and instances of the knowledge fields mentioned in the previous chapter are of key importance to this deliverable and have been captured in a relations sheet.

	KPI	Hospital Question	label	energy
Hospital Question	IAA			
label	TNO	TNO		
energy	MOW	MOW	IAA	
BIM element	DJG	DJG	DJG	MOW

Fig. 7: Image showing how the knowledge fields are placed in the relations sheet. The STREAMER partners responsible for describing the relationships are also mentioned.

In rows and columns, the aspects and instances of the knowledge fields are listed and described.

KNOWLEDGE FIELD				KPI	KPI	KPI	KPI
	ASPECT				Energy performance and efficiency	Financial analysis based in whole life costing	Quality of the environment and operational efficiency
		INSTANCE					
			DESCRIPTION	Key Performance Indicator			
Hospital Question			question relevant for hospital organizations within the scope of Streamer				
Hospital Question	Which aspects are related to the integration of the hospital into the surroundings?				Reduction of emission and potential distribution of surplus of energy production	Financial issues related to the distribution of surplus of energy production	Satisfaction of users' needs and improvement o operational efficiency
Hospital Question	Which aspects are related to the integration of planting/nature?				no relation	no relation	Satisfaction of users' needs and improvement o quality of environment
Hospital Question	Should we consider automated transport?		self-navigating vehicles / transport carts		no relation	relation to be determined in Streamer T3.3 (D3.6)	Improvement of the operational efficiency
Hospital Question	What should we consider to lower the total cost of ownership?				Evaluation of the energy performance and efficiency	Data related on the whole life costing gives information on the waste of money that could be avoided and savings that could be obtained	Improvement of the operational efficiency

Fig. 8: Screenshot showing a fragment of the relations sheet with rows and columns (appendix).

At the intersections of these rows and columns, a text has been provided to describe the relation. There are three different text options:

a) description of the relation

b) "no relation"

c) "relation to be determined in STREAMER T (task number) + explanation

The sheet contains 1955 fields that have been provided with information.

991 fields (51%) are “no relation”

0 are relation to be determined in STREAMER WP1

29 are relation to be determined in STREAMER WP2

13 are relation to be determined in STREAMER WP3

0 are relation to be determined in STREAMER WP4

8 are relation to be determined in STREAMER WP5

0 are relation to be determined in STREAMER WP6

0 are relation to be determined in STREAMER WP7

914 fields (47%) are described relations

The relations to be determined in other WPs involve WP2, WP3 and WP5. This information will be communicated to the responsible task leaders for consideration.

To improve readability, conditional formatting has been applied to the sheet: when there is no relation, the cell is grey. When a relation is to be determined in another STREAMER task, the cell is green.

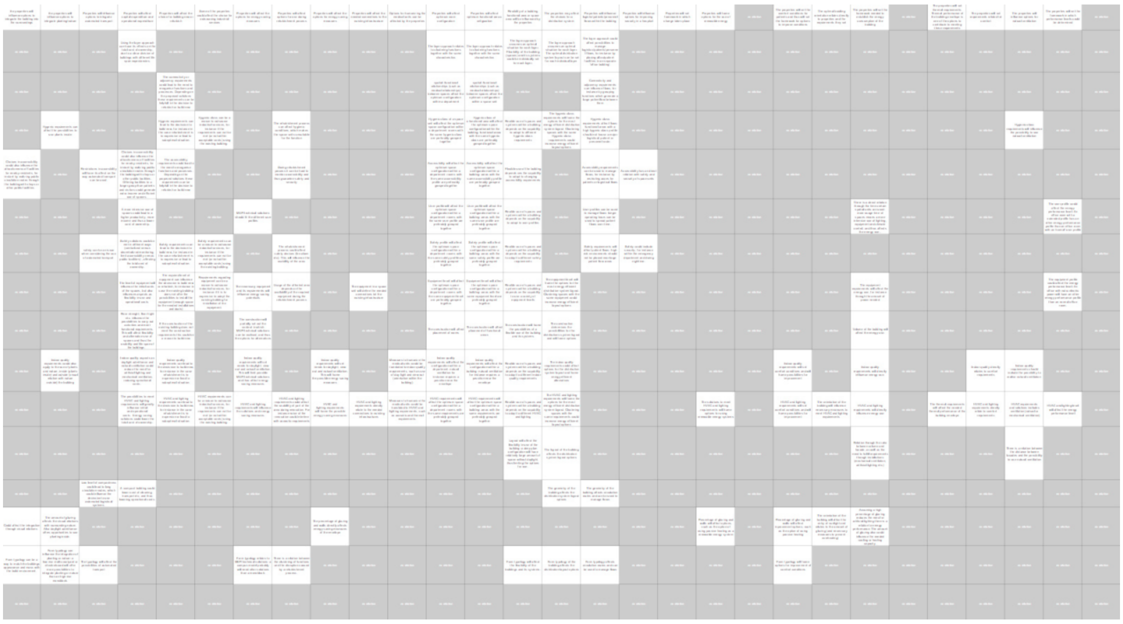

Fig. 8: Screenshot of the relations sheet showing how concentrations of relations can be visually identified (appendix 1)

An example:

One of the hospital questions is: “Which systems can we implement to improve comfort conditions for patients in summer and winter?” Related aspects from the relations sheet are: (descriptions of the relation are between brackets):

Labels:

- Indoor quality (Indoor quality requirements will set comfort conditions and will frame possibilities for improvement).
- HVAC and lighting (HVAC and lighting requirements will set comfort conditions and will frame possibilities for improvement).

Energy:

- Ventilation on room level (Ventilation system can improve comfort condition in the room).
- Lighting (Better lighting conditions improve comfort conditions all year long).

BIM:

- The PoR (Requirements related to patient comfort should be in the PoR).
- Building envelope (Building envelope properties are related to patient comfort (e.g. openable windows).

KPI:

- Financial analysis based on whole life costing (Financial sustainability of measures to improve comfort condition)

This information will help the stakeholders to understand which information and responsibilities are related to one specific aspect of the design, in this case a hospital question. Some conclusions that can be drawn from this example:

- At least two labels should be incorporated in the design.
- The MEP engineers should pay special attention to lighting and ventilation aspects.
- A recommendation for the hospital is to include requirements related to patient comfort in the PoR.
- The architect should pay special attention to the building envelope.

The relationships between the BIM and the other aspects (In the description of work, this is referred to as “the conversion of existing energy-efficient buildings guidelines into semantic rules for BIM”) are the basis for BIM design template development in 1.6.

5. Current and future developments in STREAMER

5.1 Implementing knowledge from D1.5 into the BIM

In current practice, some of the aspects related to BIM can be easily implemented into the BIM. To summarize:

- The labels can be attached to the PoR, mass, functional area and room components. This has been demonstrated in WP7.
- How and if the labels should be attached to building envelope, structural elements, building services, medical and user equipment and interior finishes is to be researched.
- How and if the KPIs and energy aspects should be attached to the BIM is to be researched.
- The hospital questions should not be attached to the BIM. Hospital questions have been added as knowledge field to this deliverable for the purpose of relating the other aspects to real-world design considerations.

5.2 Challenges in BIM workflow

File formats: the IFC format used for BIM exchange is currently not used as a modelling file format by common architectural BIM software; IFC files are generated by export only. Most analysis software is IFC based, which means that the analysis will not take place in the modelling environment itself. The designers would profit from an immediate response from the analysis software while modelling.

Conversion/mapping from native file formats to IFC sometimes results in a more complicated workflow. For example, functional areas and rooms (in Revit and ArchiCAD, these coexist within a single model/file) are both converted to IfcSpace. In the IFC format however, IfcSpaces are not allowed to overlap. This means separate IFC files must be generated to represent the spatial elements in a single Revit/ArchiCAD file.

Data compatibility: Not all data in the IFC file is recognized by all (energy) analysis tools. To be researched is if it is relevant to create property sets especially for STREAMER, if these cannot be “read” by the analysis tools.

5.3 Dependencies and recommendations for other STREAMER work packages

Deliverable 1.5 will provide input for:

- WP2: relations between energy and BIM aspects might provide suggestions for further development of EeB solutions.
- WP3: relations between the KPIs and other aspects might provide suggestions for further development of the KPIs.
- WP4: relations between the PoR and other aspects might provide suggestions for further development of the PoR.

- WP5: knowledge related to the BIM aspects will help to determine which properties should be used in the BIM family template.
- WP5: the information and relationships will contribute to capturing and formalization of requirements (who is responsible for which information at which stage of the design).
- WP6: relations between the PoR and other aspects might provide suggestions for further development of the requirement model.
- WP7: the labelling system can be incorporated in the test cases on the short term. We can test for which purpose they can be used.

STREAMER deliverables that have provided input for D1.5:

- D1.1: the labelling method has been re-used and updated.
- D3.1: the KPIs have been re-used.

In STREAMER D1.6, research will likely focus on:

- Possibilities for integrating the sheet developed in this deliverable into the REQCAP system developed by AEC3.
- Conversion of the relations sheet to a database structure.
- Expansion of the database with knowledge developed in other STREAMER deliverables.
- Visualization of relationships, making the data more easily accessible.

Deliverable 1.6 will provide input for:

- WP6: values associated with BIM aspects will be used to develop rules for design validation / configuration. An example: design validation on room properties can verify if a patient room categorized as “hygiene class H3” (this information is provided in D1.6), is accordingly labelled in the model.
- More relationships with other STREAMER deliverables are to be determined.

References

n/

Appendix 1 – Relations sheet