D4.4 Techniques of knowledge management in participatory semantic-driven designing

Deliverable Report: 4.4 Final version

Streamer - Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems.
The Streamer project is co-financed by the European Commission under the seventh research framework programme FP7.EeB.NMP.2013-5 ; GA No. 608739)

Streamer
European research on energy-efficient healthcare districts

D4.4 Techniques of knowledge management in participatory semantic-driven designing

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Dissemination PU

Document history

Version	Date	Status	Produced by	Comments
1.0	18-08-2016	Draft	Bektas, E., Brouwer J.	First full draft, for review WP leader
1.1	23-08-2016	Final draft	Brouwer, J., Vermeulen, P, Cleason-Johnsson, C.	Final preparations for draft deliverable 4.4 – In the pursue of approval, we need to address the KM issues in chapter 3 more specific. Validation and external review needs to be done.
1.2	26-08-2016	Final Draft ready for Submission	-	Revised last remarks contributing partners

Colophon

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Publishable executive summary

Health care buildings and districts, ranging from academic hospitals to care facilities for the elderly, have all in common that they are venue of many activities, much logistics, and in continues operational stage. The design and construction of health care facilities is for that reason an utmost complex task and the area of many specialists and experts. In order to design a most optimal health care building, the exchange of information and knowledge in the design process is evidently one of the most important conditions for incorporating all relevant perspectives in the building or renovation plans.

Underlying report treats the concept of knowledge management, within the wider context of participatory semantic driven design processes. What is understood with knowledge management, how does knowledge management looks like in ordinary design processes, and how arer STREAMER project results enable to improve, structure and fasten the complex interplay between all relevant stakeholders in the design process of a heath care district.

How knowledge is retrieved, how it is made applicable and what tools can be used to help structure, organise and record this know-how, all are questions that have been answered per design stage. From the first moment, the strategic definition, via brief and concept design, up to the detailed design, is analysed for their knowledge management capacities. How are the STREAMER tools being used for maximizing the impact of knowledge available, and making the right decisions at the appropriate moment in time is what is the ideal outcome. In the analysis, the subsequent design steps have been elaborated with regard to the key aspects of knowledge management, breaking ground for further recommendations on what still could be improved for the optimisation of knowledge management in future design processes.

Departing from the inventory of techniques for knowledge retrieval, topic of deliverable 4.3, we built it up to the full encompassing management of knowledge in hospital design processes. Not disregarding the fact that also after the design has finished, and construction started, or even the operation and maintenance phase is current, the role of knowledge management is less important. One could argue that most relevant knowledge is to be gained from the *as is* situation, for instance of how the hospital building is operating in reality, how the HVAC techniques are handling, and what future renovation projects need to be aware of. All very relevant information, but for the scope of STREAMER a little bit far of, we have decided to remain within the realm of (early) design only.

List of acronyms and abbreviations

- BIM : Building Information Model
- EeB : Energy efficient Building
- DBFM : Design, Build, Finance & Maintain
- IFC : Industry Foundation Classes
- IPD : Integrated Project Delivery
- PoR: Programme of Requirements
- PPP : Public – Private Partnership
- PLM : Product Lifecycle Management
- EBD : Evidence Based Design
- KPI : Key Performance Indicators
- EDC : Early Design Configurator
- MCDA : Multi Criteria Decision Analyses

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1. Introduction

Main Objective

The current deliverable considers how techniques for retrieving relevant and necessary knowledge and experience for the use of optimizing the health care design process, can be integrated in the semantic design model. To do so, a theoretical approach is set up by the introduction of the Knowledge Diamond. This model will connect the overview of techniques to retrieve the experience and knowledge (including tacit know-how) from end users and experts, with the management of sharing & retrieving knowledge – not only the information, but also the correct/meant interpretation of this information. Furthermore, the sub-stages of Design Management are generated. The aim of this deliverable is to discuss the next generation of knowledge management techniques in light of the semantic driven participatory design.

1.1 Aim of the deliverable

1.1.1 Position within STREAMER

In the end of deliverable 4.3 an analysis was made that resulted in strong recommendations clearing the road towards this deliverable (D 4.4), where the next generation of knowledge management techniques is discussed in the light of semantic driven participatory designing. The aspects drawn in this deliverable will bridge the knowledge retrieval techniques described in 4.3 with the management of sharing & retrieving knowledge. This is not only true for the information itself, but also for the correct interpretation of how the information was meant.

As described in the DOW; this deliverable will focus on the techniques of knowledge management in participatory semantic-driven design process. STREAMERs semantic knowledge management supports the complex decision making process related to the diagnostic and management tools, to thus improve the clients organisational performance. The optimisation of this design process is put in a balanced match with the needs and wishes of the different stakeholders and the different perspectives.

1.2 List of techniques from D4.3

Deliverable 4.3 provides an overview of the current state of the art of the techniques that help to retrieve relevant information and knowledge from experts and users by the design team. The form and type of information can range from legislation, codes and directives, up to experience levels of various end-users (i.e. patients, staff, visitors, service providers such as caterers, maintenance operators etc.). The deliverable identifies six techniques and elaborates on their ability to retrieve knowledge from experiences or information sources elsewhere, and feed this into the semantic design process. The six techniques are[1]:

[1] STREAMER Deliverables 4.3, Bektas, E., Brouwer, J., Techniques for Knowledge Retrieval - Techniques to retrieve expert and user experience and tacit knowledge to be integrated in the semantic design models, Delft 2015

- Establishing Programme of Requirements (PoR)
- Making Ontologies
- Creating Applications
- Organizing Physical Settings as Expert or User Workshops
- Prediction Models
- Procurement Methods

To link these techniques for the STREAMER process, the concept of the knowledge diamond will be introduced in Chapter 2.

1.3 Design Phases from RIBA

The Royal Institute for British Architects (RIBA) is one of the most prestige, internationally best known and widely referred knowledge institute for architects. Providing standards, trainings, support and international recognition to member architects, to peak in their profession. In their effort to champion better buildings, communities and the environment through architecture, they provide a generally accepted and much applied plan of work, being the standard UK model for the building design and construction process (see Appendix 1).

1.3.1 **Illustration of phases**

RIBA stages, Plan of Work (2013)

For common understanding and communication purposes the RIBA standard model for building design and construction process description is used. This standard is used to depart from a common understanding of the objectives of each stage, a clear distinction between stages, and the proper hand over materials to move from one stage to the next. We have mapped the various materials and tools developed within the STREAMER project on this standard model, and have been able to categorise the tools applied in relation to the main aspects of knowledge management, in order to establish an improved system of interlinkages and recording of knowledge for the future.

1.4 Reading Guide

In Chapter 2, a theoretical framework will be set up. In this, the concept of the knowledge management will be researched, and the concept of the knowledge diamond will be introduced. The chapter deals with the relationship between the knowledge diamond and the six techniques identified in deliverable 4.3 in heading 2.2. Furthermore, this chapter will provide illustrations of what ideal knowledge management would look like.

In Chapter 3, the design management process in STREAMER is set out. The sub-stages of the design process in relation to STREAMER are described: Strategic Definition, the Preparation & Brief phase, Concept Design and Detailed Design.

In Chapter 4, a detailed analysis is made. The RIBA design phases are set out against the STREAMER design steps, and the ideal way of knowledge management in a theoretical manner is defined. The chapter also provides a synthesis for STREAMER: new procedures define new rules and regulates the process.

In Chapter 5 an analysis is made of the need of knowledge management for STREAMER. It also provides a glimpse of the future of knowledge management. Finally, the chapter gives several recommendations.

2. Theoretical approach (knowledge diamond)

2.1 The knowledge diamond

Designing a hospital is not easy. Intuitive, unsubstantiated decisions made during the design phase, could have major risks for patients, staff, and the operationality of a hospital: it could reduce patient and staff satisfaction, lead to higher maintenance costs, or even pose a threat to patient safety. To prevent such issues, proper ‘knowledge management’ is crucial. Knowledge management is a more hands-on way of dealing with knowledge and content. Although easily mixed-up, knowledge management is not the same as the knowledge retrieval techniques described in deliverable 4.3. The description in deliverable 4.3 refers to which techniques are out there, whereas this deliverable is about knowledge management and concerned with how to manage these techniques. Knowledge management is thus more practical. In a definition, it refers to: “explicit management strategies that focus on the process of acquiring, creating, sharing, utilizing, and storing intellectual assets and other stimuli from internal and external business environments, which facilitate an organisation to perform successfully”[2]. In other words, knowledge management aims to facilitating the creation, access, and reuse of knowledge - by people, processes, and technology. It deals with the optimization of knowledge to achieve set goals, not only through various technologies, but also through tools and processes.

To spot which techniques deal with which aspect of knowledge management, a framework was set up by Esra Bektas (TNO). Her *Knowledge Diamond* Framework summarizes the management of sharing and retrieving knowledge[3]. The scheme is not just about sharing and retrieving information, but also about correct and meaningful interpretation of that information. It emphasises that there are different dimensions to knowledge, which all require different ways of retrieving. The four dimensions in the knowledge diamond concept, are:

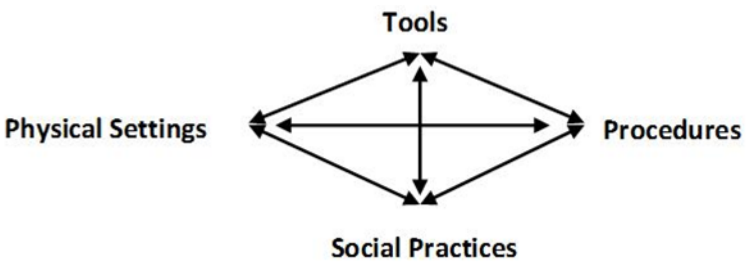

Figure 1: Knowledge Diamond Framework, illustrating the four dimensions, key aspects of knowledge management (Bektas, E. 2013)

The first dimension in the knowledge diamond is “Tools”. Tools refers to the design of specific models and methods that support activities to retrieve and share knowledge. Examples of tools are 3D Models Visualizers, BIM applications, Simulators, etc. Tools enable the knowledge management and interaction necessary for

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[2] Huber, G.P. (1991). “Organisational learning: The contributing processes and the literatures.” Organization Science 2(1): 88-115.
[3] Bektas, E. (2013). “Knowledge Sharin Strategies for Large Complex Building Projects.” Architecture and the Built environment, TU-Delft #04/ 2013

retrieval. Its acts more like an infrastructure. Various techniques can be used for tools here. Software, and hardware for designing, creating a repository, search engines and so on, just illustrate the large diversity in this section.

The second dimension in the knowledge diamond is “Procedures”, contextualized as rules and norms that regulate knowledge retrieving and sharing processes. Examples are diagrams, flowcharts, or guidelines making the way of doing things explicit. A perfect way to exemplify this type of making knowledge explicit and retrievable, is a handbook.

A third dimension is “Physical Settings”, specifically important for the tacit knowledge. Physical settings enable people to observe each other and have direct interaction on what is being shared. An example of a physical setting dimension is a workshop.

The fourth and final dimension is “Social Practice”. This refers to a social structure resembling a project based sharing community, in which boundary crossing activities are promoted (including exchange of information, informal and formal interaction, and collaborative interpretation of design information). Social practices have three different levels of engaging actors:

1) Individuals who generate knowledge, apply this to their works, and visualize objects
2) Design crews performing both personal and collaborative knowledge sharing processes
3) Design teams, in which managerial and operational level actors contribute to multidisciplinary knowledge.

People in the three levels engage in different social practices, as they hold and carry different organizational and disciplinary perspectives, agendas, methodologies, and hierarchical positions. Examples of social practices are client teams, representatives of a design team, and managerial, executive technical level actors.

2.2 Relation between the knowledge diamond and STREAMER

The techniques identified in the aforementioned deliverable 4.3 can be linked to the abovementioned aspects of knowledge management. In this section, each of those techniques will therefore be connected to one (or two) of the four dimensions of the knowledge diamond.

2.2.1 Establishing a Program of Requirements (PoR)

The first technique, establishing a Program of Requirements (PoR), can be linked to two of the dimensions of the knowledge diamond. First of all, the PoR is a tool, as it offers a specific model and method for retrieving and sharing knowledge. The online PoR is especially perfect as a tool for sharing knowledge, since it allows the client to create and modify the PoR by using a webservice or webpage. It is easily accessible and can be kept up-to-date as the project evolves. User rights can be customized and a change log registers which input has been changed by who, when and why. All of this makes the online PoR into a highly useful tool, with a seemingly clear place in the knowledge diamond.

However, the PoR is not just a tool: it is also part of a *procedure*. In the preparation and brief phase the PoR is a necessary element – without it, it will be impossible to set up a design. Furthermore, the PoR offers a framework on how requirements should be written down. In that way, it is a sort of standard for the registration of stakeholder demands. The online PoR particularly makes retrieval and sharing of the process easy: it makes knowledge explicit and retrievable.

2.2.2 Making Ontologies

The second technique, making ontologies, can be linked to the *procedure* dimension of the knowledge diamond, as an ontology contains concepts, relationships (for example between rooms), properties, and the constraints (or rules). It is a form of regulating knowledge; setting up rules and norms. An ontology offers a common and shared structure among the various parties, which helps indexing information (documents, plans, etc.).

2.2.3 Creating applications

The third technique is the creation of applications. This is a clear *tool* in the knowledge diamond framework: it supports activities to retrieve and share knowledge. In each design process a number of different software tools and applications are involved. In STREAMER, for instance, software application could support the transformation of a PoR into an at least rudimentary design model. This also shows the previously mentioned aspect of different technologies helping different tools: a software application is a technology *helping* a tool (the PoR), while *being* a tool at the same time.

2.2.4 Organizing Expert- or User Workshops

The technique of expert or user workshops, first of all has the dimension of a *physical setting*: it facilitates the face-to-face interaction of people, experts and users, to create, share, integrate and re-use knowledge and experience. During the design process, many design activities require meetings and workshops in order to enable the design to proceed. More than most forms of communication, this face-to-face interaction can result in tacit knowledge. Expert- or user workshops thus have a conspicuous place in the physical setting dimension.
However, expert- or user workshops can also be seen as a *social practice.* As stated earlier, social practices include project-based sharing communities which promote cross-boundary activities. This also covers design crews and design teams (contributing to knowledge sharing processes and multidisciplinary knowledge). In expert- or user workshops, such crews or teams could evidently meet – consequently, the “Social Practice” dimension can also be found here.

2.2.5 Prediction Models

Prediction Models is the fifth technique mentioned in deliverable 4.3, and falls under the *tool* dimension, as it concerns a specific model/method. A prediction model is a way of capturing knowledge by integrating experiences and factual findings of existing properties, or to establish relations between pre- and post building interventions. It is a model to learn from previous interventions, to establishing and re-use knowledge. An example of a prediction model is the Evidence Based Design Model (EBD). This is a perfect example of why prediction models fall under the tool dimension: the model captures and re-uses knowledge from a variety of sources.

2.2.6 **Procurement Models**

Procurement Models is the final technique and falls under the p*rocedure* dimension, as the example of the IPD (Integrated Project Delivery), mentioned in deliverable 4.3, illustrates. The IPD scheme differs from traditional delivery approaches in the high-aimed level of collaboration between the project participants (for example, between the owner, the principle designer, and, the prime-constructor), from the very early design stage to the final hand-over. The early sharing of information and insights gained from a diverse set of stakeholders promote knowledge sharing and increase workflow efficiency for all project participants. Therefore, the IPD model functions as a framework for (new) integrated contract forms. It regulates the knowledge retrieving and sharing process, which are aspects of the procedure's dimension: by an increase of knowledge, a better understanding of the project is created earlier in the design process.

2.3 Ideal knowledge management by illustration regarding the RIBA phases

In 1963, a model for the building design and construction process was set up: the RIBA Plan of Work. Since then, it has been a foundational document for the architect's profession and the construction industry, providing a shared framework for the organisation and management of building projects, which is widely used as both a process map and a management tool, and providing important work stage references points. These, in 2013 revised "RIBA-phases" of the plan of work, consist of:

- Stage 0, Strategic Definition (Identify client's Business Case and Strategic Brief and other core project requirements.)
- Stage 1, Preparation and Brief (Develop Project Objectives, including Quality Objectives and Project Outcomes, Sustainability Aspirations, Project Budget, other parameters or constraints and develop Initial Project Brief. Undertake Feasibility Studies and review of Site Information).
- Stage 2, Concept Design (Prepare Concept Design, including outline proposals for structural design, building services systems, outline specifications and preliminary Cost Information along with relevant Project Strategies in accordance with Design Programme. Agree alterations to brief and issue Final Project Brief).
- Stage 3, Developed Design (Prepare Developed Design, including coordinated and updated proposals for structural design, building services systems, outline specifications, Cost Information and Project Strategies in accordance with Design Programme).
- Stage 4, Technical Design (Prepare Technical Design in accordance with Design Responsibility Matrix and Project Strategies to include all architectural, structural and building services information, specialist subcontractor design and specifications, in accordance with Design Programme).
- Stage 5, Construction (Offsite manufacturing and onsite Construction in accordance with the Construction Programme and resolution of Design Queries from site as they arise)
- Stage 6, Handover and Close Out (Handover of building and conclusion of Building Contract)
- Stage 7, In use (Undertake In Use services in accordance with Schedule of Services)

RIBA sets out 7 stages, with roughly 4 phases in it: the strategic definition phase (0), the Preparation and Brief Phase (1), the Concept Design Phase (2), and the Developed Design Phase (3) (see appendix 1).
Placing these next to the knowledge diamond, it is important to remember that there might be different tools focussing on different phases, which compile different types of knowledge (from construction, operation, maintenance phases), different types of people (energy experts, end-users as patients, medical staff, researchers/visitors, contractors, etc.). There might be different groups of people involved in each design phase, each using different tools. Thus there is a need for sufficient emphasis on procedures and physical settings, as they are the glue to the way tools are used and knowledge is shared within a particular phase (see preparation and brief phase, and the knowledge diamond seen earlier), and throughout the overall design phases. For the latter, see the big diamond consisting of small ones referring to each phase below:

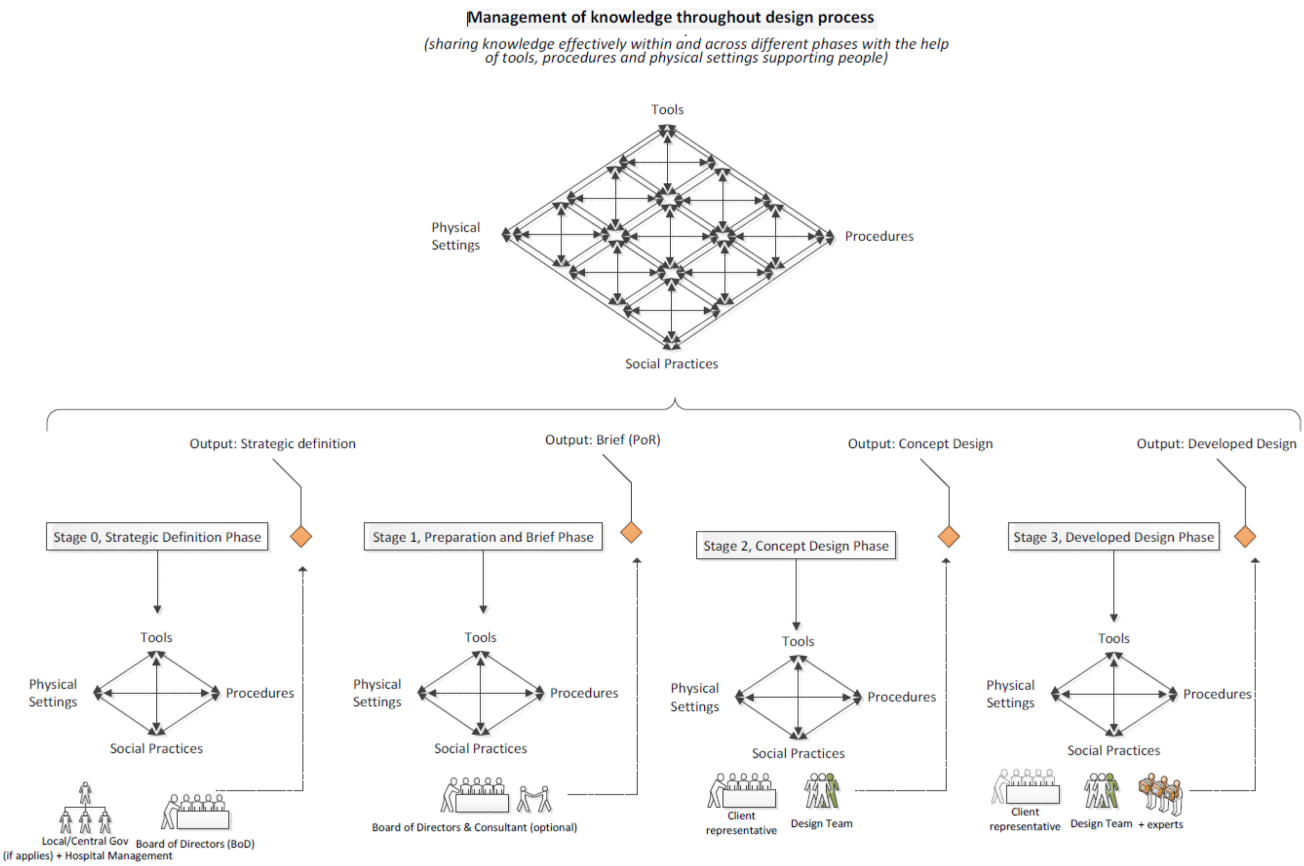


Figure 2: Illustration of management of knowledge throughout stages of design process

The image shows that there are different tools developed within the STREAMER project. These tools deal with different aspects of design and might only focus on a particular design phase (i.e. the Early Design Configurator does not deal with Detailed Design). The STREAMER tools capture information (reflecting knowledge and experiences of people from previous projects/experiences of people/previous regulations, etc.). Such information is often necessary for the following phase (s). In other words, the origin of knowledge can come from different phases and sources and from different forms of information. Tools are the most effective way to use explicit and implicit knowledge. Procedures are effective to generically describe the way knowledge is to be shared (i.e. use of tools, content gathering, process flow, etc.). Physical Settings are the most effective way to accommodate dialogues of people who have different expectations and terminology, and to reach a common understanding. They provide moments of proper interpretation of the information shared by others, via face-to-face conversations. Eventually, these three promote sharing of knowledge among people and result in “social practices”.

For example, tools like BriefBuilder and dRofus are called database approaches, as they create PoRs in a ‘smart way’. They re-use information mainly coming from different projects, regulations or requirements and known hospitals in operation. User experience –patient satisfaction components – is one concrete example. Another example is comfort conditions of rooms in a hospital (component).

3. Design Management in STREAMER

3.1 Sub-stages of the Design Process in relation to STREAMER

The creation of a hospital does not happen overnight - it happens in stages that often take months at a time. Furthermore, the process is not one of simply drawing up some ideas and implementing them: it needs tools – one needs to set up a design, calculate the costs, etc. In the previous deliverable (4.3) several of such tools were set up for STREAMER, for instance Semantic Labels, the Early Design Configurator (EDC), MCDA, Cost Calculator, etc. In this chapter, these tools will be put into the framework of the RIBA phases of the design process: the Strategic Definition, Preparation & Brief, Concept Design, Detailed Design. Considering the early design stage of the health care building design and construction process, most of STREAMER's results and deliverables are focussing on the early stage decision making.

3.1.1 Strategic Definition

Far before a formal brief is being developed, and basically the decision is made to make a renovation or new construction to be executed, a long process of decision making, scenarios, context analyses has taken place. This stage is labelled "strategy definition" in the most recent RIBA design process, as step 0. Its description reads: a project is strategically appraised and defined before a detailed brief is created. This is particularly relevant in the context of sustainability, when a refurbishment or extension, or indeed a rationalised space plan, may be more appropriate than a new building. Identify client's Business Case and Strategic Brief and other core project requirements.

Based on an interview with Marc Koster, Manager Strategic Real Estate of the RNS, we have been able to construct a figure of the current internal (hospital management) decision process to come to an approached project application (for either renovation, for new construction, extension or similar).

It all basically starts with a process analysis. Looking at the functioning, for instance production (number of patients, medical surgery, client satisfaction etc.), the results of the analysis could determine the needs of a specific department in terms of production surface and equipment. Buildings follow function is the main ranking. from the starting point is the general policy document(s) of the hospital, which in turn results from the analyses of the wider context. The generic policy document(s) treats demography, technology, and changing needs and requirements from patients, staff and the society in general. Certain trends also influence what changes are to be expected in the near future, from specialization issues to expectations from patients in regard to single rooms etc. Medical science and technology also sometimes require specific type of care and facilities to be offered.
From the generic policy document(s), trend analyses are carried out including the wider (policy, legal) context, in order to allow a more specific translation to be made into long term requirements for healthcare real estate. A careful balance is made between the current state of real estate (type, age, location, m2, specs) and the use (production) now and expected in the future. This leads to further development of location profiles (in case of multi

location healthcare models) and the optimization / specialization of healthcare operations. The output is a long-term strategic real estate plan and an additional policy document that includes more of the future requirements in terms of hospital buildings, in response to the changes to occur in the wider societal and medical context.

This strategic real estate policy document provides the fundament for certain rebuild/renovation projects to be initiated. For example, expecting a growth in first aid medical care, this should be facilitated by an extension of the first aid department in the hospital building Y. It could also result in moving some other departments in or out, and thus creating additional space. For RNS, the strategic real estate plan is based on 10 years foresight and includes three possible future scenarios. Each scenario provides a specific business case, meaning that costs and profits should be in balance, for the hospital too. Discussion with banks, healthcare insurances complete this picture, and is prepared in financial terms based on the changes to be realized within the ten years ahead. All scenarios for renovation, extensions, moving and reconstruction are to be formulated in a so called project application form. In the light of the generic financial budget (a hospital building depreciation over 50 years in the books), each project application should be concluded with a feasibility study. The strategic real estate policy document provides a set of scenarios, giving decision support for the hospital management to make a decisions between the various strategic choices: refurbishment, new construction, or moving specific departments, to create some more space for others. All these decisions can be planned for to ensure that over time the balance between the real estate available at the hospital district meets the needs of the client. Each decision needs to be supported by a project application form. These project application forms will be judged and evaluated by the hospital own advisory group (incl. some representatives of the Management Team). Validation is based on a set of criteria, among them:

- To what extent does the project contribute to patient satisfaction?
- To what extent does the project support the objectives of the general policy
- Does the project initiate from a legal commitment?
- What is the risk (safety) if the investment / project is not realized?
- What is the size of the target group affected/helped?

Based on the scores of the criteria, the project application obtain a certain ranking, a priority for execution. It is only after the investment committee approves the project in financial terms, and determines if the investment fits within the cost statement of that year, that an advice is provided to the Members of the Board to make a positive decision to the project application. It is only after the Board has made the decision, and in some cases also including an approval from the committee of supervisors, that a project application is approved and is moved to the project execution stage. A person within the real estate department takes over the project after approval, and this person leads the project into formulation of a formal brief, PoR, design, etc.

Partners having a particular stake in terms of what the future in healthcare demands from the hospital to be prepared for are local, regional and national governmental authorities. The future demands should also be formulated in terms of sustainability, flexibility, specialization, etc.

NOTE: Description of the Strategic Definition stage here above is based on one single case study, RNS from the Netherlands. It might very well be that in other healthcare cases in the Netherlands, and also in other EU countries, the specifics of policy documents, order and decisions are dealt with in a different way.

3.1.2 Preparation & Brief

For pedagogic and communication purposes, a common standard process description is used in this deliverable. The RIBA plan of work has been chosen. This standard was developed by RIBA (Royal Institute of British Architects) and is widely used. The RIBA plan of work is used in order to reach a common understanding of the objectives of this phase but also make mapping with the STREAMER methodology possible. According to the RIBA plan of work (2013), the core objectives of the preparation and brief phase are:

“Develop Project Objectives, including Quality Objectives and Project Outcomes, Sustainability Aspirations, Project Budget, other parameters or constraints and develop Initial Project Brief. Undertake Feasibility Studies and review of Site Information.”

More extended information can be found in a guidance description in the RIBA plan of work:

“Several significant and parallel activities need to be carried out during Stage 1 Preparation and Brief to ensure that Stage 2 Concept Design is as productive as possible. These activities split broadly into two categories:

- developing the Initial Project Brief and any related Feasibility Studies
- assembling the project team and defining each party’s roles and responsibilities and the Information Exchanges.

The preparation of the Initial Project Brief is the most important task undertaken during Stage 1. The time required to prepare it will, of course, depend on the complexity of the project.
When preparing the Initial Project Brief, it is necessary to consider:

- the project’s spatial requirements — the desired Project Outcomes, which may be derived following feedback from earlier and similar projects
- the site or context, by undertaking site appraisals and collating Site Information, including building surveys
- the budget.

A project Risk Assessment is required to determine the risks to each party. The development of the procurement strategy, Project Programme and, in some instances, a (town) planning strategy are all part of this early risk analysis.
The importance of properly establishing the project team cannot be underestimated, given the increasing use of technology that enables remote communication and project development using BIM. For Stage 2 to commence in earnest, it is essential that the team is properly assembled. This is discussed further in Deliverable D4.5 in respect to Integrated Project Delivery.

According to the RIBA plan of work (2013), the key supported tasks of the preparation and brief phase are:

“Prepare Handover Strategy and Risk Assessments.

Agree Schedule of Services, Design Responsibility Matrix and Information Exchanges and prepare Project Execution Plan including Technology and Communication Strategies and consideration of Common Standards to be used."

The intended end result is thus an initial project brief, which includes quality objectives, project outcomes, sustainability aspirations, project budget, the site and context. Recommended is to develop a project risk assessment and handover strategy, that includes schedule of services, a design responsibility matrix, information exchanges. Furthermore, it is advised to develop a project execution plan including technology and communication strategies and, especially for STREAMER driven project, consideration of common standards to be used.

The preparation and brief phase builds on the previous phase by using the strategic brief and business case as input. The strategic brief will be enhanced during this phase, and, by doing feasibility studies and benchmarking the initial brief is validated. A certain amount of information must thus be available in order to make benchmarking possible. This information could include budget versus spatial requirements and/or determining a sustainability goal. The validation through benchmarking and feasibility studies will also narrow the range of design possibilities. Next to the validating of resources and scopes, more information (e.g. more precise budget information, site information etc.) will reduce the number of design options as well, and the further design utilisation will be more directive to resources and requirements, see also figure 3.

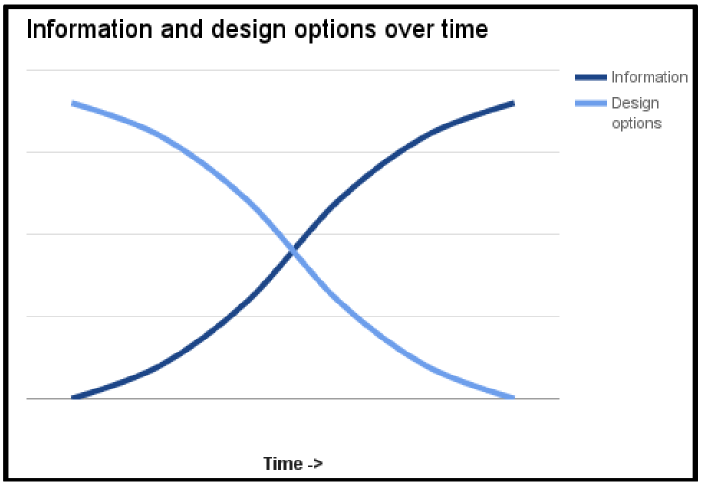


Figure 3: Relation between information and design options over time

When applying the STREAMER methodology (as a combination of all tools and know-how fitted in the STREAMER process approach) it is important to have a common understanding of used standards and the STREAMER vocabulary. The STREAMER vocabulary includes typological room names, typological functional area names, generic requirement labels and design rules (STREAMER Del 6.1). Besides, it proofs to be necessary as part of the handover strategy (after the end of STREAMER into real application) to determine what specific tools (software, methods) are capable of supporting / applying the STREAMER methodology and who of the involved stakeholder will “push the buttons” of those tools. Correct data exchange is an important requirement to fully use the whole range of STREAMER tools. So this must be part of the risk assessment and known before the design stages begin and even at time of determining the initial brief.

Currently, the initial brief is often stored as a digital document (e.g. PDF, Word) or a sheet (e.g. EXCEL or Google sheets). This is also the case for public tenders. **A state-of-the-art solution** would be to use a semantic database like Briefbuilder or dRofus, where the initial brief is a static export of an online database. *The semantic database allows the user (the client) to track wishes and requirements from the user and reuse information from other projects.* The link between the online semantic database can remain in a BIM workflow by the application of an URL property in the BIM model. Briefbuilder, for instance, can generate a room typology URL that can be loaded directly into a Revit model. The room typology is linked to an actual part of a room, so all original data can be retrieved at all times and the original data can also be enriched with the model data.

The semantic database can also be a common thread throughout the project lifespan. As information is stored online, the comments and feedback from users can be mapped and can be managed better. The data is then reused in a BIM model as a reference link, this link could be bi-directional where the new information from the design process can be written back to the database. In either way, the original data and source can always be retrieved and validated with current design. For example a comparison between the required square meters from the Brief with the actual square meters in a design can be easily carried out. With special modules in dRofus and Briefbuilder, the same database can also be used for Facility Management purposes.

As said earlier, data exchange is of outmost importance within a STREAMER driven project. STREAMER driven projects require a specific, formalised and finalised PoR as import for the EDC. This PoR is enhanced with label information and typological references and is exported as a CSV file. The validation of the used vocabulary and used structure is in the EDC itself. The EDC will reject PoR files that do not follow the vocabulary and structure. If, for instance, a PoR derives from a tender, the PoR will probably not use the needed structure and must be adapted or even interpreted before being exported to the EDC.

In situations with public tenders, the PoR will not likely be prepared in a STREAMER format. It takes time to translate the program into the STREAMER vocabulary and structure and will possible cause translation problems. The standard dictionary that maps the initial brief into STREAMER room types with default labels helps in this process. But this extra investment at the start of a project could be a threshold for adopting the STREAMER methodology. If a tender uses the budget per stage as a criterion to determine the best party, the parties that use the STREAMER methodology will probably be at a disadvantages. This is as more resources are spent in the early phases of a design in relation to a more traditional design process. An often encountered pitfall in contemporary desing processes is that the managements divide the process into smaller phases and tries to optimize each phase. However, one of the main benefits of putting more effort and focus on the early design phase is that the quality will be higher as the client’s requirements and wishes are more thoroughly treated and understood. Furthermore, by adopting the STREAMER approach, introducing all relevant actors at an early stage, the final design documents have a higher level of buildability and thus limits the risk for re-design (requests from the construction site) and a higher level of customer value is achieved. It is clear that this discussion must be taken at a very early stage, in the implementation of the new way of thinking, in order for everyone to understand the benefits and what to expect from each stage.

The use of a semantic PoR database cannot be adopted if it is not applied at the start of a tender. The investment in resources, for example, collecting user specific request and reusing data from previous projects, would afterwards be too high to apply such a tool, without achieving the full added value.

For further reading on how to set up an effective integrated contract model, or work with (public) tenders calling for integrated contracts, and how to organize the information exchange with all relevant stakeholders in that preparation stage, see deliverable 4.5.

The use of the STREAMER vocabulary helps in the early phases of a design process to close the information gap. Little information is available at this early stage. Therefore, some generalisations, assumptions and defaults are used mainly translated in typological models and requirements labels. The typological models include room typologies, functional area typologies and more country specific systems like, NBHI developed layer typologies[4]. The requirements are generalised into labels, which groups several requirements in a container: the label. Another example are the MEP typologies which are described as generic systems.
To ensure that the same assumptions, generalisations and defaults are used by all the partners, it is important that the standard is set at an early stage and is fixed. Consider for instance that a cost advisor uses a bare minimum for walls, which results in a positive outcome for the initial costs. However, the climate engineer may at the same time simulate the energy performance of the building with very high standards regarding insulation for the same wall. This will lead to a positive energy performance and a possible energy efficient acceptance for the building. Without a project standard, this will result at a later stage in unexpected higher costs or a lower energy efficiency. So in respect to knowledge management, the assumptions, generalisations and defaults have to be shared among all the involved partners, possibly stored at a central location.

The mapping from a traditional PoR towards a STREAMER label enhanced PoR could be carried out more automated. A solution is already made available for this application, in testing the STREAMER workflow and for WP7 workshops. A google sheet environment is made where a dictionary is incorporated. This dictionary will translate a user-given name in a room type defined by STREAMER. This room type is automatically used to fill in default label values. This surely will decrease the time especially for more common rooms. Still, these values need to be validated, because every project is unique. Another tool that can do more or less the same thing is Briefbuilder, which is enhanced with a STREAMER output template.

Functional relations can be stated in a document and translated to design rules. As some functional relations are often contradictory to each other, not all the functional relation can be met in a design. Therefore, the design rules can be reused in a validation tool to determine which functional relations are met.

[4] NBHI (Netherlands Board for Healthcare Institutions; "Building Differentiation of Hospitals – Layers approach" Report number 611 – 2007, Culemborg, the Netherlands

The design rules can be derived from different sources:

- Functional relations;
- Expert knowledge;
- Client knowledge;
- Preferences;
- Building regulations;
- Building norms;
- Best practices.

These sources require different approaches for knowledge management. Building regulations, building norms and best practices can be shared and updated from a centralized source. Other are project specific while other are user specific. The project specific rules need development in the preparation and brief stage as these are unique for the project. If an expert in the group already has experience with a STREAMER driven design, he/she will already have some expert knowledge captured in design rules. If applicable, these rules can be reused in this project, as these reflect the expert knowledge. One thing to consider is that the expert knowledge is often associated to the expert's home organisation's business case, which must be respected. If the design rules representing expert knowledge are open for other competitive businesses, this could mean they lose some of their market advantages and unique selling points.

Functional relations can be checked against building regulation to ensure that they do not contradict each other. Other relations and requirements can be checked by the client and his/her advisors on consistency by their expert view.

Other inputs required for the next phase are that of a building mass and site information. The site/context analysis will be translated to a building form as an input for the EDC, including a geographical location and orientation. This information can be stored in any format as it requires a manual input into the EDC. Often the shapes derive from a masterplan or a mass study. The size will be determined by the relation between requirements and budget/costs.

Determining the project size goes from global to detailed level. By first using key figures to determine the budget according the requested spatial program or vice versa, the two criteria can be determined and specified. Feasibility studies will determine if an approach is feasible or not (e.g. try to place the requested program in a predicting building volume, or determine the financial consequences of a certain building envelop).

A thing to consider is that one of the ultimate goal for project STREAMER is to reduce energy use with 50%. The STREAMER methodology is focused on the function-related consumption of energy and not necessarily the facilitative consumption of a building. The mass of a building could greatly impact the energy use of a building. The shape and orientation must already been determined before applying it in the EDC. So any energy, quality or financial aspects relating to that shape and orientation must be validated before the step of applying the EDC.

Another possible option is to do a mass study using tools like Sefaira or Energy Analysis for Revit that are able to simulate energy performance for this stage where little is known, even cost related aspect can be roughly calculated. In this way, the building shape is also including aspects of energy and costs at this early stage.

Based on the RIBA task description regarding roles, the following roles can be identified and enhanced with STREAMER specific tasks:

Client and/or Client Advisor

- Contribute to development of Initial Project Brief including Project Objectives, Quality Objectives, Project Outcomes, Sustainability Aspirations, Project Budget and other parameters or constraints;
- Contribute with the translation of the PoR to the STREAMER vocabulary.

Project Leader

- Develop Initial Project Brief with project team including Project Objectives, Quality Objectives, Project Outcomes, Sustainability Aspirations, Project Budget and other parameters or constraints;
- Collate comments and facilitate workshops as required to develop Initial Project Brief;
- Prepare Project Roles Table and Contractual Tree and continue assembling and appointing project team members;
- Prepare Schedule of Services and develop Design Responsibility Matrix including Information Exchanges with lead designer;
- Review Project Programme and Feasibility Studies;
- Prepare Handover Strategy (e.g. BIM protocol, STREAMER tools, data validation), Risk Assessments and Project Execution Plan;
- Monitor and review progress and performance of project team;
- Contribute with the translation of the PoR to the STREAMER vocabulary.

Lead Designer

- Where required, Contribute to preparation of Initial Project Brief;
- Contribute to assembling of project team;
- Contribute to preparation of Handover Strategy and Risk Assessments;
- Comment on Project Programme;
- Monitor and review progress and performance of design team;
- Contribute with the translation of the PoR to the STREAMER vocabulary;
- Check STREAMER PoR on consistency of terminology and consistent use of labels.

Architect

- Contribute to preparation of Initial Project Brief;
- Discuss project with appropriate planning authority;
- Undertake Feasibility Studies (could also be done with the EDC, as designing is an iterative process this is not yet the concept phase, which begin with an official milestone, the initial Brief, although this brief is properly not static as well);
- Prepare Site Information report;
- Input to determine the building mass;
- Contribute with the translation of the PoR to the STREAMER vocabulary.

Building Services Engineer

- Contribute to preparation of Initial Project Brief;
- Contribute to Site Information report;
- Contribute with the translation of the PoR to the STREAMER vocabulary.

Civil & Structural Engineer

- Contribute to preparation of Initial Project Brief;
- Contribute to Site Information report;
- Contribute with the translation of the PoR to the STREAMER vocabulary.

Cost Consultant

- Contribute to preparation of Initial Project Brief;
- Prepare Project Budget in consultation with client;
- Input needed to determine the (maximum) size of a building;
- Contribute with the translation of the PoR to the STREAMER vocabulary;
- Ensure that budget is described as life cycle cost and not only initial budget.

Contractor (depending on contract form chosen)

- Ensure buildability aspects of the Initial Project Brief and knowledge of market conditions

Synthesis

The project starts with the business case and the strategic brief. This will be developed into a more detailed initial project brief, project objectives and site information. More (detailed) information will help to narrow the range of design possibilities and validation of the original brief and objectives. For a STREAMER driven design attention is needed on the handover strategy as the STREAMER methodology require specific data exchanges, vocabulary and software tools. At least a PoR in a specific structure and specific used vocabulary in CSV format is needed for the next phase to be used for the EDC.

3.1.3 Preparation and brief phase to develop the concept design

According to the RIBA plan of work (2013)[5] the core objectives of the preparation and brief phase are:

"*Prepare **Concept Design**, including outline proposals for structural design, building services systems, outline specifications and preliminary **Cost Information** along with relevant **Project Strategies** in accordance with **Design Programme**. Agree alterations to brief and issue **Final Project Brief.**"*

For the STREAMER process approach, there are some significant developments made in this stage, which will lead to an enhanced workflow for the Concept Design Stage. For better understanding this concept design stage is divided into two sub-stages with a clear beginning and ending;

- **Sub-stage 1: Early Design**. Includes the development of layout alternatives by the EDC by applying design rules and a building hape to a PoR. These alternatives will be validated through an early KPI analysis on Quality, Energy performance and LCC. There is also a possibility to enhance the layout alternatives with MEP specific information in generic systems comparison and layout.
- **Sub-stage 2: Concept Design**. Takes the considered alternatives into a new iterative design process with the same outcome as the RIBA defined stage description. With some STREAMER specific recommendations.

Sub-stage 1, Early Design, is closely related to EDC tool developed within the STREAMER project. So first a short summary of the EDC process is provided herewith (see further fig. 4).

In the conceptual design phase, the brief information (usually a program of requirement, (PoR)) and information from the feasibility studies, including site information, are used to create an early design. This can be done by creating hand drawings, CAD drawings or simple Building Information Models. In order to support the actors (from the construction supply chain) with producing early Building Information Models including easily generating different variants of the building, the Early Design Configurator (EDC) was developed. The EDC is intended to bridge the gap between the description of the space requirements and the first space layouts. In order to start the process, at least two data sets must be available:

- A program of requirement (PoR) (see previous section)
- A minimum set of design rules

[5] Sinclair, D. (2013). RIBA plan of work 2013 overview.

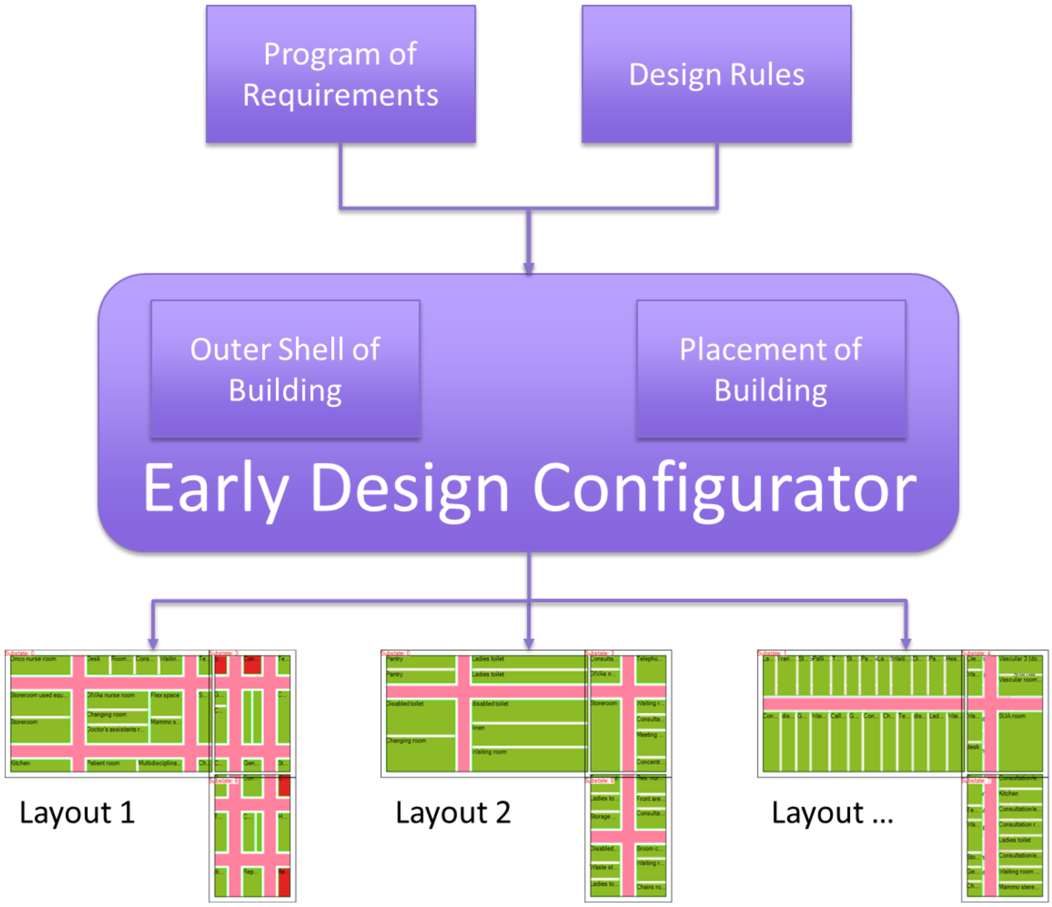


Figure 4: Information flow of the Early Design Configurator

The figure above illustrated how the information flow is dealt with in the EDC. Beside the two data sets mentioned above, information about the building and the site is required. In order to feed the EDC with this information, a graphical user interface is provided.

The result of this process is a number of design alternatives, which can differ in the building shape and in the floor layout. Finally, all collected information, including the information available from previous processes is stored in an openBIM (IFC) model. These design alternatives in IFC models are compared based on the Key Performance Criteria, which process step is facilitated by the Multi Criteria Decision Model developed in WP 3.

Information used in the EDC to create the design alternatives are finally stored in the Building Information Model (except for the design rules). This includes:

- A BIM project with a unique identifier
- A construction site with the global position (latitude/longitude) and the building orientation (north direction)
- A building with default systems for lighting, ventilation and zones, which are grouping the spaces according to the functional areas given by the PoR
- A number of storeys

- Necessary building elements (walls, slabs and roofs) including geometry, base quantities (Gross Area, Gross Volume, Nominal Length, Nominal Width, Nominal Height), CAD Layers, colour information, material and connection information
- Spaces with calculated geometry, PoR information, base quantities (Gross Volume, Nominal Height, Gross Wall Area, Gross Floor Area, Gross Ceiling Area) and corresponding space boundaries

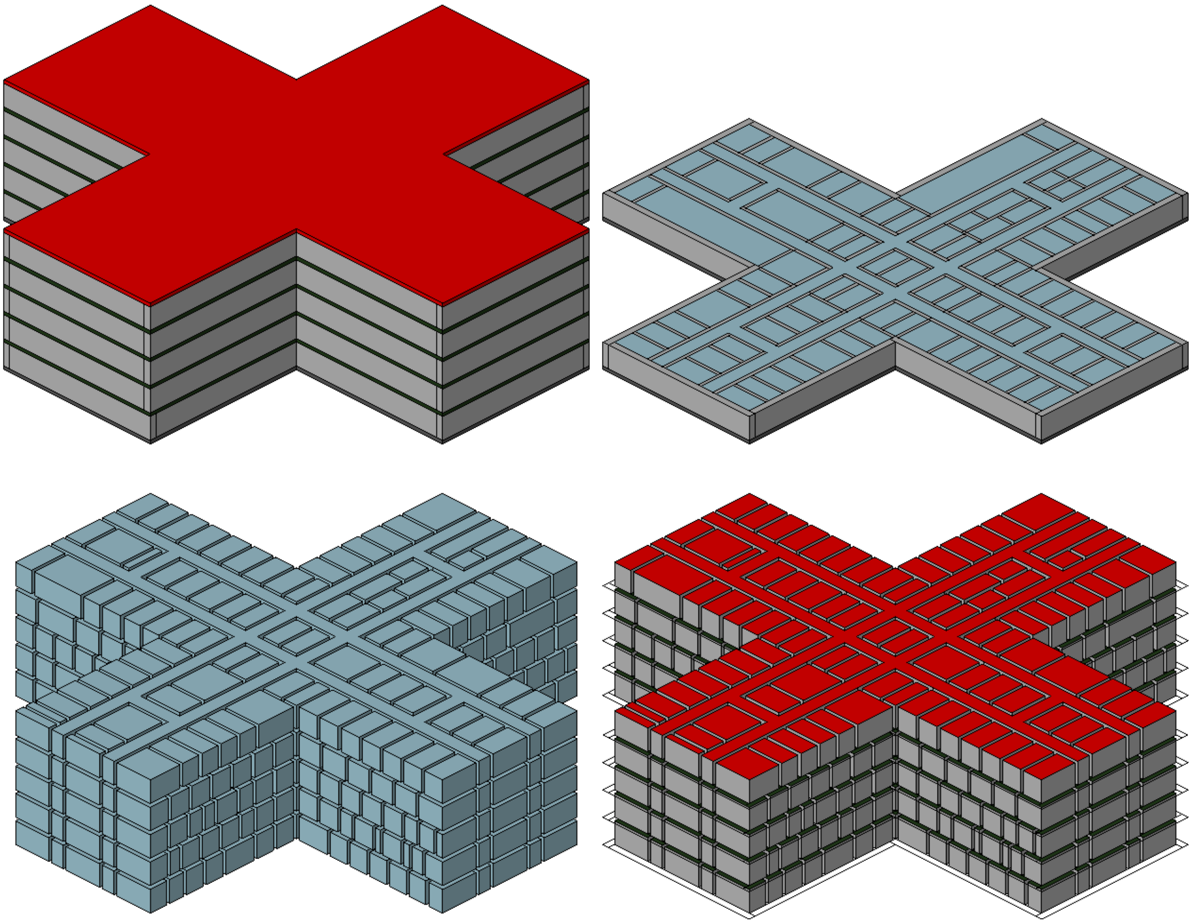


Figure 5: Examples of an IFC output of the EDC (upper left: the complete model, upper right: one storey, lower left: the created space geometry, lower right: the space boundaries.

In the figure here above, it clearly shows an example of the IFC export of the EDC. The model is created to support downstream applications like energy calculation/simulation tools as well as design tool like REVIT for the following design steps. In the first case, the space boundaries are a significant entity of the model. Together with the material properties of the surrounding building elements and the STREAMER Labels of the spaces, they can be used to perform a heat demand calculation. The second case, it is important to provide all information of the building elements like geometry, material (even material layer), building element type and CAD layer, to ensure that the design applications can work with the model like a native model.

If the result is stored in an ordinary file system, a separate file must be created for each alternative. If, for example a content management system is deployed, the alternative of a project can be stored as different revisions of the same model.

The alternatives of outer shapes of the building and layout variants are used to estimate key performance indicators (KPI), which evaluate the concept design models regarding:

(1) The energy performance and efficiency;
(2) The financial analysis based on the whole life costing and;
(3) The quality of environment and operational efficiency (see further WP 3 results).

In order to find the most suitable solution, the alternatives, enriched by the estimated KPIs, are imported into a STREAMER decision making tool. The tool is capable of displaying the performance on the KPI's of multiple design alternatives in a comprehensive way for the group members. In this way, the most promising alternative can be selected and handed over to the next design sub phase. Alternatively, also multiple alternatives can be selected if there are resources available to develop those further.

A possible iterative design loop is the choice for a certain generic MEP system in this stage. MEP options are filtered on a room by room base. This is basically the compatibility of a certain MEP system with the (label) requirements of the room.

After this, a choice must be made on a higher level as not every room can have its own individual MEP system. The choices on these larger scales (e.g. group, department, floor or building) can be seen as design alternatives as well. And these alternatives need also the validation through the KPI simulation.

The urban plan activity is covered by the building form and site input in the EDC. So a choice on these aspect need already been done before a layout can be generated.

The outcome of the EDC with spatial layout alternatives covers the main form and layout activity.

The structural design can be integrated by selecting a grid in the EDC, the wall thickness, the building form and with the requirements set in the construction label. Although this is not very explicit, so some additional information in a stage ending document is recommended.

The development of the urban integration of the building in the area activity for instance need some explanation in diagrams, drawing and/or texts as a BIM model is not self-explaining regarding those aspects. As a further development of the EDC pointing an entrance was mentioned as a possibility. The position of the entrances will be part of the urban integration of the building.

The design of the functional and spatial layout can be developed faster in the second sub-stage in comparison with a traditional design process. Most of the functional and spatial layout will be set in the Early Design sub-stage as part of the EDC outcome and a choice for a certain layout based on KPI performance. So big changes to the original outcome of the first sub-stage will make the KPI performance unreliable as the KPIs are based largely on a certain room layout. But it is certainly not unthinkable that a layout will change some bit as the first outcomes are generic and are in need of being made specific. New information from the design process will alter the layout as well. Important is to validate later layout by using for instance the Design Validator (Developed within

STREAMER WP 6). The Validator checks the consistency of a later BIM model with the original assumptions. Another KPI check could also be valuable to check if the new design is still heading in the right direction.

Designing the architectural appearance is something that is in need of further developing after the Early Design sub-stage. The main structure will be developed there with a certain room placement but not an architectural concept or appearance of the building. The objects in the Early Stage are generic and do not have any characteristics other than requirements and dimensions. So the architectural appearance need to be developed in sub-stage 2. This can be done with diagrams and drawings but a preferred direction is to include it in a BIM model, working with the previous information.

The outdoor area design is not part of the EDC, so a basic conceptual design for the outdoor needs to be developed. Possible input is site information, building form and location of the entrance(s). These need to be translated into a model, diagram or drawing.

Recommendations regarding physics can already be done in the Early Design sub-stage. As the physics are input of the Early Design Energy simulation a default can be used but a recommended approach can be validated through the KPI analysis. So this is possible in both sub-stages. The acoustic demands are already incorporated in the room requirements as a label. Possible conflict between high demand acoustics and sound sources can be identified by visual coloured representations. The sound sources still need to be identified.

The design of the main structure of the support structure, including provisional choice of material and general dimensioning activity is partly covered by the construction labels, grid and dimensioning. Combined this must be named explicit. A model can be further developed with for instance actual structural wall objects or column objects placed in a centralised BIM environment.

The choice for a certain MEP system over a group needs to be developed into a basic scheme with a general idea on distribution to fulfil the basic layout on installations activity. The generic label representing a certain system has no physical appearance and is only an attribute of another object. So to integrate the installations with the structure of the building.

The activity of integrating the design parts (architectural, structural, MEP or HVAC building service systems) is already covered by the early design as all parts are integrated in the same BIM model and validated by the KPI's. More detailed development needs further integration though. Because, for instance, no physical MEP objects are generated in the Early Design. This could lead later to spatial conflicts if this is not integrally developed. Possible also already some basic columns or structural walls need to be modelled into a BIM model to ensure full integration.

A fire safety concept is partly covered by design rules applying some building regulations like for instance fire escape route lengths. Although a design rules does not necessarily mean that the requirements will be fulfilled in a design alternative. So a check must occur, if fire and smoke compartments are needed, this needs further development from the early design.

Outcomes of the second sub-stage will lead to a Concept Design including outline structural and building services design, associated Project Strategies, preliminary Cost information and Final Project Brief which is validated through the design.

The EDC tool is a convex of the a design project. Several inputs from different stakeholders (e.g. client, architect, advisors etc.) and tools are applied in one tool. This makes the EDC a good place to have a data check as this is the bottleneck of the project. A check can be done on the completeness of the PoR regarding requirements, square meters, vocabulary etc. The output of the EDC can be checked on data consistency and on original requirements. After the EDC data streams diverse again for several specialists. For instance an IFC file for the energy simulation and an IFC file for Quality simulation. So consistency checks need to be done to ensure correct assumptions for the different simulations. A BIM manager could check the correctness of the different files for approving a simulation result. Ones again the different IFC files merge in the Decision Support tool. So this is the place to check the different IFC files from different sources on their consistency. Further development should occur in a BIM environment with agreements on file locations, used tools, experience with BIM and responsibilities. A BIM protocol will help the participant to come to this agreement.

3.1.4 Detailed Design

In the "RIBA Plan of Work 2013", the Developed Design (DD) is the third stage of the Design Process. The activities carried out during this stage include the preparation of "coordinated and updated proposals for structural design, building services systems, outline specifications, Cost Information and Project Strategies in accordance with Design Programme. During this stage, the Concept Design is further developed and, crucially, the design work of the core designers is progressed until the spatial coordination exercises have been completed. This process may require a number of iterations of the design and different tools may be used, including design workshops." (RIBA PoW 2013)

"By the end of Stage 3, the architectural, building services and structural engineering designs will all have been developed, and will have been checked by the lead designer, with the stage design coordinated and the Cost Information aligned to the Project Budget." (RIBA PoW 2013)

Historically, the tasks associated with "developed design" have been described as the "detailed design" stage, which is perhaps a clearer and better understood description.

Indeed the information necessary for the start of this stage, implemented in the early design stages (Strategic Definition, Preparation and Brief, Concept Design), are related to:

- objectives, strategies and programmes implemented within the Project Management tasks;
- programme of requirements related to the user needs;
- technical reports and drawings implemented in the Concept Design stage;
- initial estimate of costs;
- procurement strategy;
- health and safety strategy;
- maintenance, operational and management strategy.

This information and corresponding data are transferred to the Developed Design team within:

- the Programme of Requirements;
- schemes and preliminary drawings explaining the choices about building typology and conceptual layouts;
- technical reports explaining expected performances and targets that the building fabrics and MEP systems will be asked to achieve.

If the Developed Design stage is implemented using a Building Information Model (BIM), the project information model is developed based upon generic representations with approximate quantities, size, shape, location, tolerances and so on. Specification properties and attributes are developed so that the selection of systems and products is possible. Where the designer has already specified that certain building products should be used, or where there are key components that have already been selected, these may be incorporated into the model. Structural information and architectural information should develop in detail, and services design may include generic information about sizes, capacity and control systems. The model may allow early contractor engagement, and an outline construction sequence may be developed. Plans, cross sections, elevations, and visualisations may be produced as well as schedules of facilities.

When designing a hospital, a number of specialists, advisors, representative of users and stakeholders are asked to support decisions concerning both functional and technical aspects.

Given the large amount of information that is being accumulated from the various contributors it is essential that collaboration, within the design team, is managed effectively.

Using BIM it is possible to support this cooperation through the sharing of up-to-date information and problem solving. Discovering and resolving collisions which can occur developing the design solution from the concept to the developed design stage, saves money and time on the site.

BIM is also effective in optimising the opportunity for an industrial approach in the construction process, giving way to a more factory like approach, cutting down on construction time and risks of error.

Once the work of the design team has been progressed to the next level of detail, as defined in the Developed Design, eventually specialist subcontractors and/or suppliers undertaking design work will be able to progress their design work. The lead designer and other designers, where required as part of their Schedule of Services, may have duties to review this design information and to ensure that specialist subcontractor design work is integrated with the coordinated design.

Support tasks are:

- review and update the Sustainability, Maintenance and Operational and handover strategies;
- review and update the Project Development Programme;
- review Construction Strategy, including sequencing, and update Health and Safety Strategy.

The architectural, building services, structural engineering designs as well as the MEP-HVAC designs are now further refined to provide technical specification.

The use of BIM during the Developed Design stage gives an effective support reducing the conflicts, improving the reliability of the estimate of cost, providing inputs and data for simulating and optimizing the construction sequencing.

It allows for a tighter coordination during design that ultimately carries into the realisation of the project. BIM allows for extensive amounts of information to be stored in one place; this becomes a significant asset as the model becomes more complex.

As various aspects are finalised, BIM automatically generates any updates or changes throughout all drawings, saving architects considerable amounts of time. Since a number of players and stakeholders are involved in this stage, it also enables more fluidity between tasks since supporting the communication between different players and different disciplines.

Another output from the use of BIM in the Developed Design stage is the schedule of the following actions. Charts can be extracted illustrating the dependency of tasks while also allowing for the investigation of changes and whether or not they affect the critical path as well as their impact on the delivery of the project. Once a project is completed it can be saved and stored as a case study for future projects to use as reference.

The Programme of Requirements (PoR), the Early Design Configurator (EDC), and the Dashboard (Decision Support Tool), as implemented in STREAMER give a set of important input for the implementation of the Developed Design that will be implemented within the BIM model.

The PoR implemented in the previous stages gives the input to the EDC, and in the same time is the basis for the technical choices to be taken in this stage (being each room and each functional area described in detail by the labels about the performances that is asked to satisfy).

The EDC provides the designer with a set of layouts compatible with the functional requirements of rooms and functional areas and selected according to the energy efficiency related issues. In the Developed Design stage the designer will select the more appropriate layout and will develop the final solution considering the other factors related to the user needs and the client's requests.

Finally, using the Dashboard (WP 3), the designer can make a final check about the solutions selected and implemented in the Developed Design, comparing the possible options according to the results achieved in terms of energy efficiency, costs and quality.

In collaboration with the lead architect, and design disciplines along, a wider group of stakeholder can be involved depending on the type, dimension and complexity of the health care project.

The architect usually take a large role in this stage the design team, he or she often retains structural, mechanical and electrical engineers who provide the necessary design and engineering. While using a "hospital design expert" is not a requirement, many practice owners find that it's worth the investment.

The role of client and end-users (or their representatives) depends on their respective profile and on the hospital ownership (public or private), typology and dimension. Their involvement has started in the previous stages during the design brief. In this stage their role focusses on the validation of the design solutions (especially the layouts and the functional solutions) implemented on the basis of the concept design.

The contractor is responsible for actually building the project. He or she is responsible in this stage for developing a first estimation of the costs of the project and most likely is the intermediary between the client and the Township Board. Since the contractor will be responsible for building permits during the construction and for securing the final Certificate of Occupancy, during the Developed Design stage he or she will manage the relationships with the Township Board.

The civil, structural, MEP and soil engineers work with the architect to start the detail of structural and MEP solution, to design and engineer the site development work, grading, and storm drainage, to investigate the buildability of the soils on the site, to develop the specialist survey requested by the Environmental Impact Assessment.

The quantity surveyor works with the architect implementing the estimate of cost checking and advising about the financial feasibility of the architectural and technical solutions.

Individual treatment of this list of most relevant stakeholders in relation to finalizing the Developed Design in a certain healthcare building design process, illustrates the great variety of expertise, strongly interrelating when it comes to the final form and lay out of a new hospital design. Cost information, technological knowledge of materials, user satisfaction, hygiene regulations, service and building regulations, design and aesthetic aspects of design, all interfere with how the building will look like and function in the future.

Since the Developed Design stage implements some administrative tasks directly related to permits and authorizations, the stakeholders involved may include as well:

- attorney advising on legal position, rights, responsibilities, and commitments;
- facilitator/planner who knows the politics of building in the selected location (this is more frequently the case in urban, highly-developed sites);

By the end of this task, the architectural, building services, structural engineering designs as well as the MEP-HVAC designs will be developed following the project program. The lead designer will check all documents elaborated and the cost information aligned to the project budget.

The project strategies, including the energy performance of the building, will be developed further and in sufficient detail to allow the client to validate them once the lead designer has checked each strategy and verified that the cost information incorporates adequate allowances.

Other important tasks are: to obtain the authorization of local administration office and/or any other third party in relation of building regulations; to review and update sustainability, maintenance and operational and handover strategies; to review Construction Strategy, including sequencing, and update Health and Safety Strategy.

Review or update of the Project Execution Plan, including change control procedures, should be implemented to ensure that any changes to the Concept Design are properly considered.

Deliverables to be implemented in this stage are defined by the national legislation and standards that specify, in each Country, the list of documents and technical reports to be provided within the Developed Design.

The main contents of the formal documents and project deliverable generally include:

- technical reports explaining functional, architectural, structural, mechanical and electrical solutions;
- drawings including site plan, floor plans, sections and elevations in the corresponding appropriate scales (from 1:500 to 1:100);
- the estimation of costs;
- the environmental impact assessment;
- reports, drawings and schemes describing solutions and measures for safety and accessibility.

Within the European Countries the detailed lists of technical reports and drawings can change depending on the national legislation; however the basic set of documents, the technical information and the level of details have been quite harmonized in the last years.

Nevertheless, the type of documents required and levels of details can vary from one Member State to another, the actual and relevant outcomes of this stage are those related to the choices taken on the layout, that is developed in its final configuration, and the technical solutions for the building fabric and the MEP system. This allows to implement a reliable feed in for the next stage on the cost estimate, the time prediction and the programme of targets and quality levels.

“Project Strategies that were prepared during Stage 2 should be developed further and in sufficient detail to allow the client to sign them off once the lead designer has checked each strategy and verified that the Cost Information incorporates adequate allowances. Change Control Procedures should be implemented to ensure that any changes to the Concept Design are properly considered and signed off, regardless of how they are instigated. While specialist subcontractors will undertake their design work at Stage 4, they may provide information and guidance at Stage 3 in order to facilitate a more robust developed design.” (RIBA PoW 2013).

In the retrofitting projects, application of STREAMER tools in the Developed Design requires to pay a particular attention to the actual consistency between rooms and the activities allocated. It is a preliminary investigation to be done before the implementation of the new layouts for uploading the necessary information into the STREAMER labelling system: availability and accuracy of these data will make the dashboard reliable for supporting the designer in his or her choice of the best solution.

4. Analysis

In the previous chapters, the STREAMER know-how, tools and practices developed have been mapped on the RIBA stages of the early design part of the building design and construction process.

The underlying analyses is focusing on the analytical framework introduced in Chapter 2, the so called knowledge diamond, encompassing the four main aspects of knowledge management introduced in here, and the extent the STREAMER tools and practices are addressing these aspects properly for an ideal knowledge sharing in STREAMER –led design process. As for most other work packages, the main emphasis is on the tools and technologies, that STREAMER developed for ultimately support energy efficient healthcare design. The current report is intended to ensure semantic knowledge management in the design process propagated by STREAMER, including the (technical) instruments and tools being developed.. As we know that the STREAMER process is a technology driven one (due to the nature of the call of the project), rather than a process one. We further acknowledge that most tools and practices newly developed within STREAMER, and designed for fulfilling the technological demand of energy efficient hospital design, represent some challenges still regarding the knowledge management and sharing among stakeholders in the process as such.

The reasons can be found in the definition of knowledge. In tool-oriented approaches, knowledge is perceived as something to be codified and re-used via help of technologies. But the extent of knowledge embedded in such tools and technologies are often limited and mainly dealing with knowledge that can be explicated.

Besides explicated and tacit knowledge, the knowledge framework has proved that more favorable conditions need to be met for optimal knowledge management and sharing in a complex design process interaction. Conditions like face-to-face interactions, where people can ask questions, receive feedback and even identify their conflicts and differences especially regarding their understanding. The most efficient way to accommodate these interactions are organizing physical settings (i.e.co-located design, design workshops, project meetings, interviews etc.). Thus, in a project setting, organizing such events are known as an important issue but often overlooked or unnoticed regarding their importance in management of knowledge. But that is not solely enough. There are other conditions such as rules and regulations (called procedures) that support and deal with tools technologies and physical settings in relation with knowledge sharing. Again such procedures are often overlooked and underrated. And this might even be so in the STREAMER project itself. Since the project is structured across different work packages, it was unavoidable to divide them as 'technical' and 'theoretical' ones and that this division already started the challenging work and information across different partners and work packages but eventually influenced semantic knowledge management during, and within, the project. With this report, we would like to provide an 'analytical mirror' to glue the technology-driven process and identify interventions of partners within the STREAMER project that patches the challenges in technology-use and adaptation. Therefore, we use the Knowledge Diamond as an analytical model to identify such interventions and build on to that by providing an ideal way of semantic knowledge management in STREAMER-led design process. We start by looking at the self-description of design phases that the partners worked with (Chapter 3) and of which they have practical experiences. We will reflect on those phase descriptions and elaborate on what happens in terms of knowledge management (what are challenges and what are the promises, opportunities).

4.1 RIBA design stages meet STREAMER practice in knowledge management

Before diving into the elaboration of STREAMER tools and practices developed, having them allocated into the design process stages of the RIBA plan of work, and to analyse the knowledge management components addressed, we like to bring back in memory the four main knowledge management aspects:

Tools that compile necessary knowledge and experiences (by the use of techniques) to translate them into clear objectives and requirements that establishes the project ground of a design, prior to design team involvement.

Procedures that clarify the purpose and the use of the tools and regulate them in decision and design processes. Procedures are also dealing with structuring knowledge (as techniques identified before). Procedures can be on different levels or deal with different aspect of knowledge management. It can deal with use of tools (i.e. frequency, functionality, content forming) as well as organization and formation of physical settings that robust the extent of knowledge sharing or as support mechanisms to extract knowledge, experiences to transform into requirements.

Physical settings are the deliberately organized events in which face to face interaction occurs, dialogues take place. They are essential for the synchronization of work processes of different domains or parties.

Social practices are the results of all interventions regarding knowledge management on the three aspects on people and the extent that they are able to share their knowledge and interpret design information with the intended meaning and purposes.

4.1.1 Preparation and Brief Stage

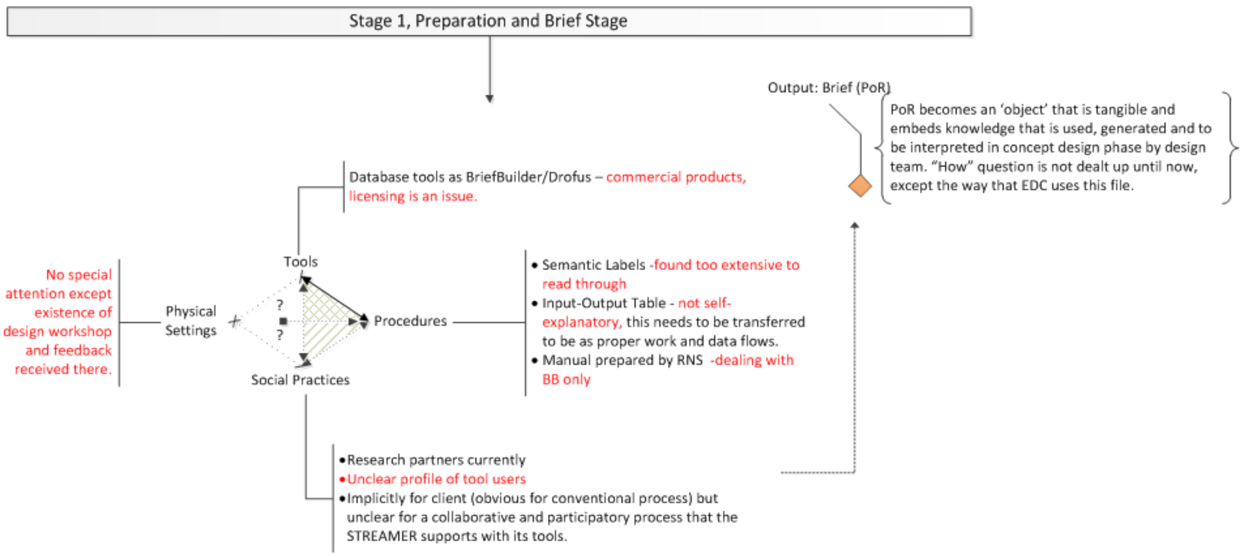


Figure 6: Analysis of Stage 1: Preparation and Brief based on the knowledge diamond framework

Figure 6 represents the analysis of current extent of knowledge sharing within preparation and brief stage. As can be observed, the prime focus of innovations can be related to the tool and procedure aspects. The database approach for creating a program of requirements (PoR) is based on semantic labels (that consists of immense knowledge regarding hygiene, equipment, access & security, comfort and user profile classes). Thus, these whole sets of labels can be referred to as 'procedure' via which the client team or the design team can define PoR on a standardized and agreed manner as labels containing minimum and maximum room properties. However, the labels needed further explanation when they were validated in the design workshop organized in the Netherlands on 30th of March 2016. Thus, while it was very clear for STREAMER partners' representatives, the Dutch practice had difficulty to get the right meaning and understanding of the labels in the process. These findings are further reported in D7.4. This area of concern needed further attention. By acknowledging the importance of both sematic labels and the database approach for creating a PoR, we therefore noticed the strong emphasis on these two aspects. There was no special attention on creating an appropriate physical setting, except the fact that design workshops are to be organized to validate STREAMER tools and design models. We will see below these design workshops as an intervention to promote face to face interaction (that ensures the knowledge sharing mostly) where people check their understanding and confirm with others. Below, we provide our analysis per aspect of the Knowledge Diamond framework.

Tools

Database tools as BriefBuilder/DRofus are to be used at this stage (Preparation and Brief stage) based on the STREAMER room library. Through these programs, a PoR is exported as a csv file format. In the next stage, the Early Design Configurator (EDC) generates early concept design alternatives based on what is defined here as requirements. This import and export procedures are done manually. However, as these data base tools, mentioned above, are commercial products, licensing may be an issue.

Procedures

Semantic Labels -found too extensive to read through

Input-Output Table - not self-explanatory, this needs to be transferred to be as proper work and data flows.

Manual prepared by RNS -dealing with BriefBuilder software only

Physical Settings

Even though no special attention during the existence of design workshop and no feedback was received on this, it seems that a collocated design approach, where all relevant actors are working together from a very early stage could be a solution. The physical space is one area of research that has received quite a lot of attention within this area more recently.

Social Practices

Research partners currently form social practices (meaning sharing people that are supported with tools and have regulations or rules of sharing via procedures).

Implicitly the tools here are for client team. This might be obvious for conventional process but the question is that how and who to be more a collaborative and participatory process that the STREAMER supports with its tools. One argument would be that via STREAMER room library and labels, it brings knowledge necessary (from other phases and experts involved there) to client team and its advisors (as people conventionally are so) and do not necessarily deal with 'real' participation. This points need attention later especially after STREAMER.

To sum up, we can criticize that the profile of users seem unclear beyond STREAMER project. The question is how and under which conditions and bonds client team, design team or consultants/advisors at this stage come together and work.

Gaps and Interventions done in this stage:

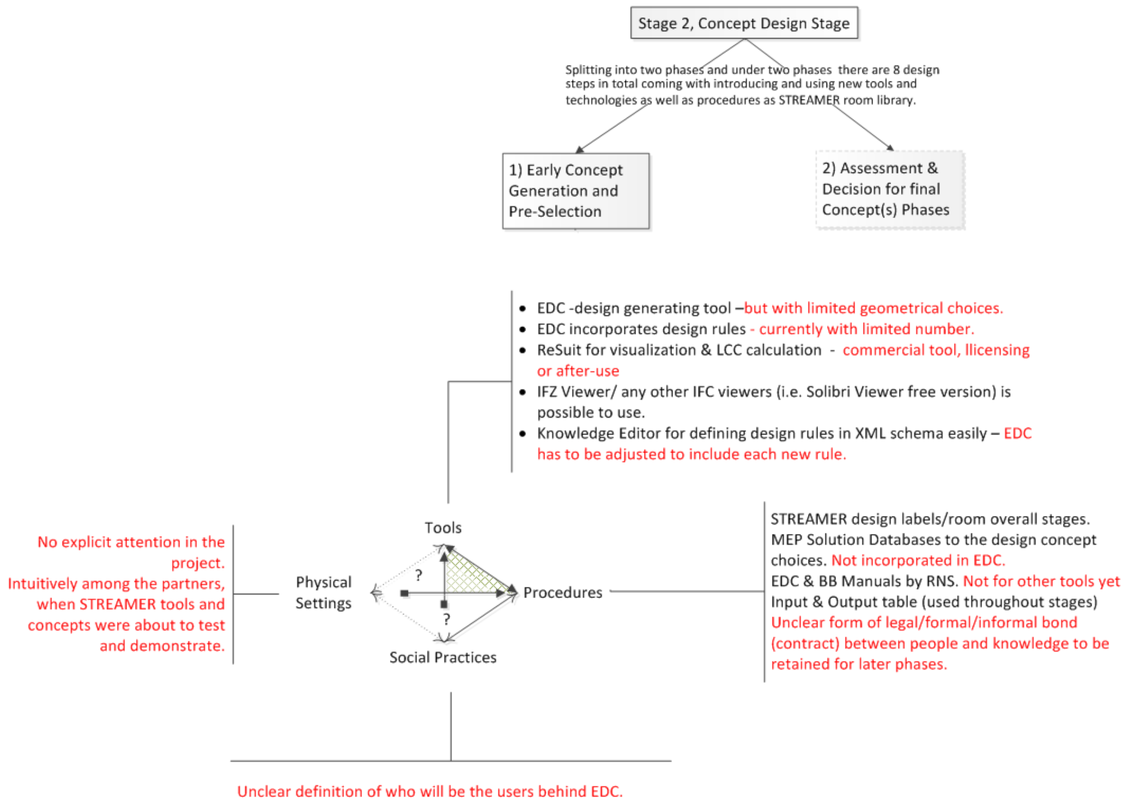
Rehearsal sessions prior to the design workshop in the Netherlands were good examples to 'physical settings'. Those sessions were needed to experience the tools and design models that were going to be tested. Up until that moment, not every partner used the tool such as Brief Builder, EDC (which we see in the next phase).

To tackle with licensing issue in future and not to promote one or to commercial party that develops database approach for PoR, the partner DJGA created a script.

4.1.2 Concept Design Phase

This phase splits into two phases and under these two phases there are 8 design steps in total coming with introducing and using new tools and technologies as well as procedures such as the STREAMER room library.

Sub-Phase 1) Early Concept Generation and Pre-Selection



Tools

Within the Concept Design phase, dedicated to generate an first order design lay out, the most important instrument to be used here is the Early Design Configurator (EDC) -design tool – which generated automatically concepts, within a given rectangular form and urban orientation/location if defined. Like mentioned in Chapter 3, it builds on to dedicated design rules, the latter which are quit limited up to now.

ReSuit that is to view concepts generated (IFC files) but also embeds calculation of LCC cost but it is a commercial tool of the partner DMO, licensing or after-use needs to be clarified. LCC calculations are based on surface areas separated by department, and if design alternatives do not contain changes in surface areas, the changes in LCC calculation was questioned as they did not change.

Thus, the PoR (as cvs file) is the base point for various alternatives that EDC generates, and in these generated alternatives, it is important to see the differences in terms of Sqm2s. The changes are of course possible if people (user) go back to the previous stage and edit PoR (with the experiences EDC gave) and then generate alternatives based on new quantities. Then comparing of the first batch and second (changed m2) can be made.

FZKViewer or eveBIM (not developed within the STREAMER) but any other IFC viewers (i.e. Solibri Viewer free version) is possible to use for siualisation of BIM alterantives created.

Figure 7: Analysis of Stage 2: Concept Design stage as two sub-stages (early design generation) based on the knowledge diamond framework

Knowledge Editor for design rules, generally comensed that if possible in XML scheme's would be preferables. More rules can be written easily, the difficulty is that for each new rule defined the EDC needs to be adjusted and incorporate these newly developed rules in a semantic way, so that EDC can generate alternatives based on such new rules. Whom is responsible for such adjustments and thus improvements (literally to include more 'knowledge' in EDC) is unclear till now.

Procedures

STREAMER design labels/room (applicable and used throughout stages) libraries again essential in order to change/see what was in PoR and this is as input to EDC (csv file).

MEP Solution Databases (STREAMER WP 2) is a database (in excel form) providing essentially input to the design concept choices. How this is incorporated in EDC, we do not know yet.

Manuals prepared to express the use of EDC in relation with the prior and later steps.

Input & Output table (used throughout stages) but same critics apply here as previous stage. These table has information on work flow and data flow but it is not easy to understand and the representation style was for convenient in meetings to reach shared understanding and consensus eventually prior to design workshop in the Netherlands. This table needs to be reproduced in a better communicative way.

The user of EDC (or users) are not really defined explicitly. This is an issue for social practices but regarding procedures, it is unclear under which form of legal/formal/informal bond (contract) the people work together and make meaningful selection of concepts that will carry knowledge for further stages and be used?

Physical Settings

No explicit attention in the project.

Intuitively among the partners, when STREAMER tools and concepts were about to test and demonstrate (within NL Design Workshop), there has been online rehearsal meetings in which every partner who takes role in the workshop

Social Practices

Unclear definition of who will be the users behind EDC.

There is quite an emphasis on tools and technology at this phase. This is no surprise. However, one interesting thing is that there is also quite work.

Sub-Phase 2) Assessment & Decision for final Concept(s) Phases

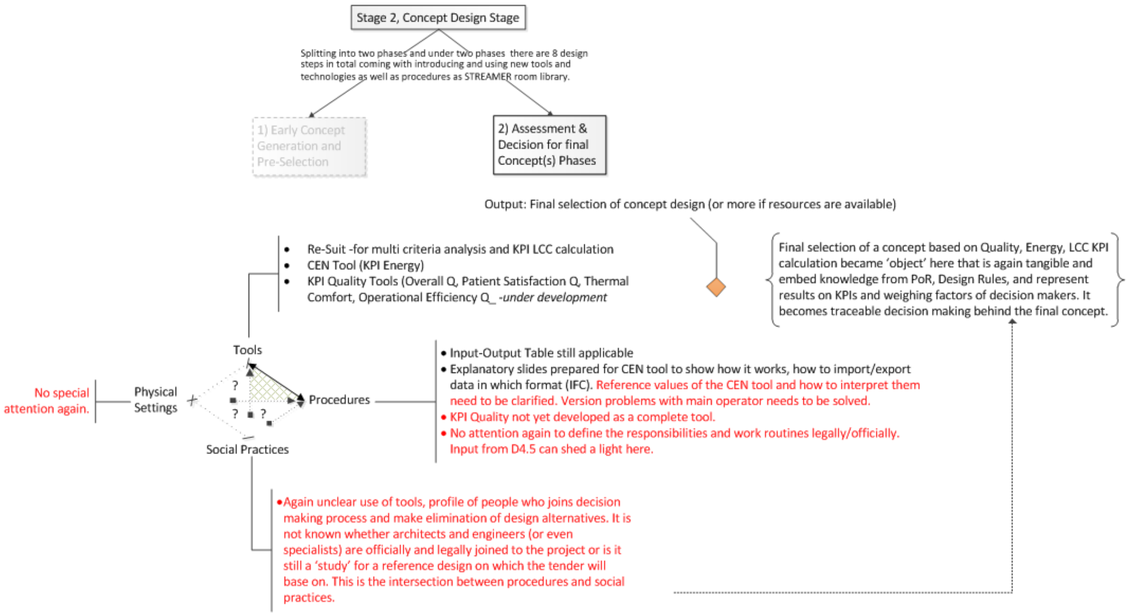


Figure 8: Analysis of Stage 2: Concept Design stage as two sub-stages (Assessment and final concept decision) based on the knowledge diamond framework

Tools

Main supporting instrument in this assessment and decision for final concept phase, is the Re-Suit -for multi criteria analysis and KPI LCC calculation tools (WP 3). These tools basically make it possible to assess the various design alternatives created by the EDC, and make it possible to rank them according to a selective set of KPI.

For energy efficiency, one of the main KPI's in STREAMER, the CEN Tool (alternative TRNSYS (by CSTB)) is been developed in this research realm and functions on the IFC standard.

KPI Quality Tools (Overall Q, Patient Satisfaction Q, Thermal Comfort, Operational Efficiency Q_ - currently under development, enables the decision makers in the end to assess and quantify the hardest of all KPI's, being the overall quality.

Procedures

Input-Output Table still applicable as it covers global work and data flow in STREAMER design process. Same issues apply as it needs to be transformed to a proper work and data flows.

There has been explanatory slides prepared for CEN tool to show how it works, how to import/export data in which format (and in which format CEN tool provides output -IFC). This is a good material but it needs to be known by the design team and by looking at those slides, someone can try out the use of the tool easily. However, it needs to include more information on what the reference values are when CEN tool provides and how to interpret results as good, acceptable or bad. This needs to be emphasized.

KPI Quality tool has not been yet developed as a complete tool.

There has been no attention yet to define the responsibilities and work routines legally/officially. Input from D4.5 can shed a light here.

Physical Settings

No special attention except existence of design workshop and feedback received there.

Social Practices

Again unclear use of tools, profile of people who joins decision making process and make elimination of design alternatives. It is not known whether architects and engineers (or even specialists) are officially and legally joined to the project or is it still a ‘study’ for a reference design on which the tender will base on. This is the intersection between procedures and social practices.

4.2 Synthesis

We have seen up to now that each stage consists of specific tools that support the process within certain particular needs per stage. These include, for example, the database approach for PoR and the EDC for the concept design stage. However, each tool creates its own knowledge diamond and, consequently, different aspects need to be tackled. In other words, whenever there is a new tool and technology introduced to support a specific design stage, there needs to be new procedures defining rules and regulations of that particular sub-process (i.e. if there are new sub steps come along with the tool, making those explicit) and face to face interaction that provides best the extent of shared knowledge in the design process. The defining of new rules and regulations as procedure, is often associated to physical settings and crucial for validating and learning how the new tools’ uses and gain experience. Up till now, we have seen limited attention to this aspect (in the STREAMER project, and beyond). Therefore, they result in challenging situation for people in order to know what to be shared, where to share (repository) and in which bond/ network they will be working in and share their knowledge with. If those aspects in new tools, in a design stage (incl. sub-stages), are not well addressed and considered, optimal knowledge management and sharing in that stage and subsequent stages will become difficult to incorporate as a consequence. Examining the figure 4, one is able to observe that the large knowledge diamond at the bottom, representing the whole knowledge sharing and management of an energy efficient hospital design project, is actually build up by smaller pieces, smaller Knowledge Diamonds, interacting and interrelated. Each smaller knowledge diamond, related to a specific design stage, or even use of tool/ technique, has its own knowledge management aspects to take into account. If somewhere in this interrelated process, the information flow, participation by client or semantic nature of the design process is not fully included, this might impose difficulties to the optimal management of knowledge throughout the whole design process as such.

We can conclude this synthesis by stating that the analysis provide arguments for unequal attention and addressing of all knowledge management aspects in the building design process for where it concerns the novel STREAMER tools and practices introduced. Prime attention has pointed to the development and inclusion of novel tools and requires as such the implementation of new procedures; but very much lacks the inclusion of social practice and physical setting.

4.3 Ideal way of knowledge management on theoretic manner

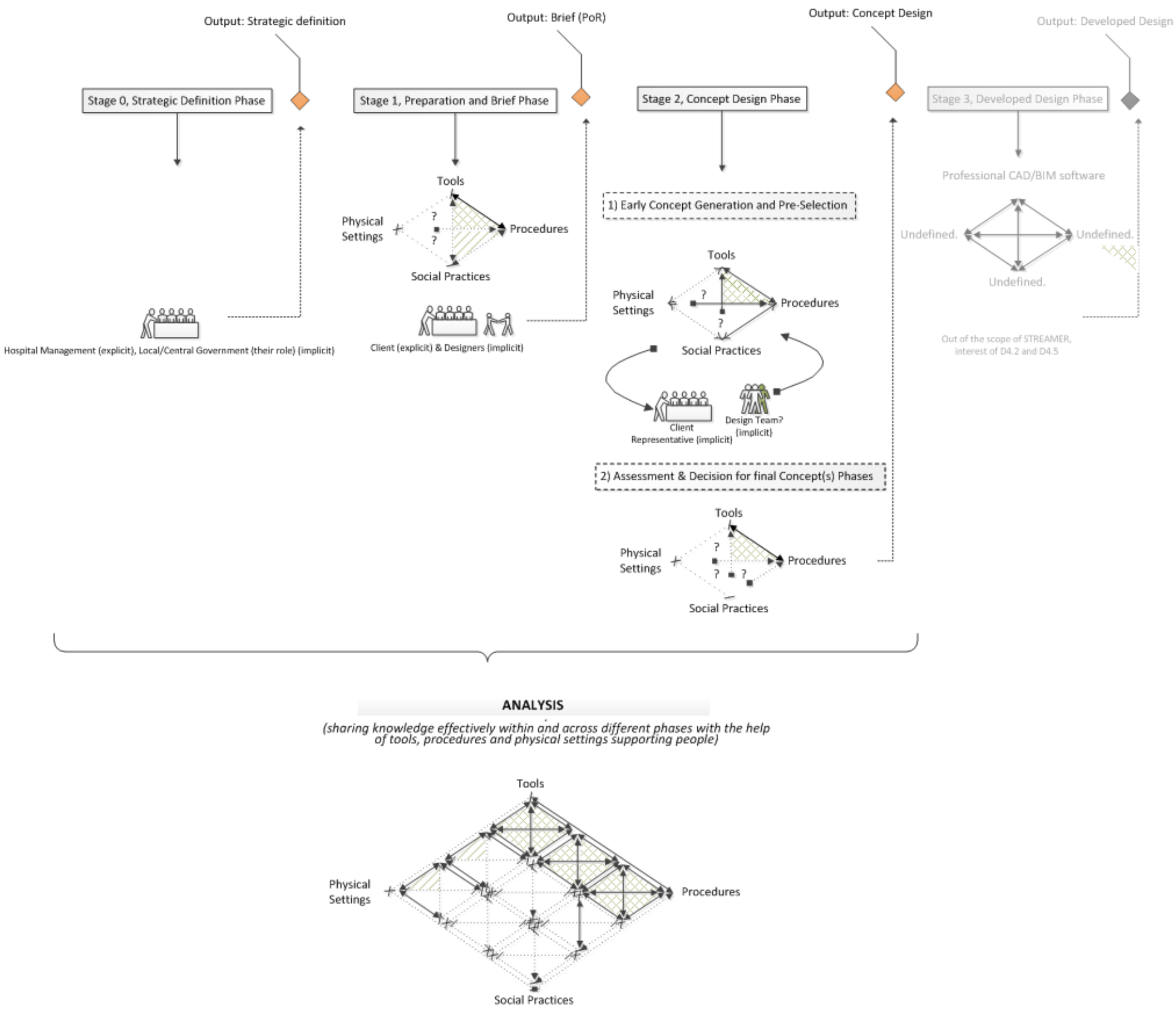


Figure 9: Synthesis based on analysis of each design stage, based on the knowledge diamond framework

The main message of Figure 9 is to illustrate that there are several tools, procedures and physical settings available within the generic design practice, but they are applied differently in each specific design stage. This is so to speak ''micro knowledge management', in each sub-stage, and depending on type of stakeholders involved. Each sub-stage, prepares the ground for the next to build on further. Therefore, it is for the knowledge capture, storage, and ultimate application (management in general) of the results in the next stage. It is important to address the four knowledge management aspects, in each of the sub-stages, to ensure the maximum effect of the semantic knowledge management throughout the STREAMER design process.

So overall, the tools and instruments specific for a design phase might be used by different actors (or some actors may not involve in a next stage). Provided that the management of knowledge in one specific design sub-phase is well addressed and sustained (mostly in early phases) this will help to assure the knowledge transfer to the next phases.

In an ideal world, everything is synchronized within the phases and across the phases. The people forming social practices are clear and therefore the way that tools and innovation support people are also clear. In other words, the main questions of each phase include what are the new tools or technology, for whom are they intended and how do these tools and technologies support the teams. Furthermore, a clear understanding of how this new methodology differs from a conventional process must be clear In our analysis we have identified clear challenges regarding the required profile of the actors as well as lacking attention on the physical settings.

5. Recommendation and Conclusion

5.1 The need of knowledge management for STREAMER

In order to improve the use, application and retrieval of relevant knowledge for optimised health care district designing, the STREAMER project has developed a wide set of tools, procedures and instruments (incl. know-how of application) over the past 3,5 years. This deliverable reports on the analyses that has been carried out on the extent of these tools and procedures are able to manage the knowledge from stakeholders over the various stages of the health care district design process effectively.

Above all, the report provides sufficient arguments that the STREAMER tools address three out of four major aspects of effective knowledge management, specifically considering the application in a participatory, semantic-driven design process. It further illustrates the room for improvement, directed to the social practice and physical setting, where the design process is taking place. One suggested recommendation to make the social practice and physical setting still part of the consideration of knowledge management issues in the realm of STREAMER tools and practices presented, is to have them as objective of validation included in one or more of the design workshops planned in the last period of STREAMER.

As recognized by the RIBA, in a section for professional support focussing on the health care clients, it is underlined that the conventional planning practice is not sufficiently equipped for the complex interplay between the demography, epidemiological and economic challenges that the healthcare districts will be facing in the near very future.

Stakeholders involved in the design process are not always are equipped with sufficient skills (capacity, knowledge, experience) to formulate adequate strategies for overcoming resource constraints, inflexible procurement routes and deal with the disconnection between capital on the one side, and operational costs on the other.

On top of that, the hospitals have to deal with an increasing amount of different care models, making a design difficult to brief successfully upfront. The need to comply with the complications of different standards and norms, often stands in the way for applying innovative and creative design solutions. Following these recommendations, we encourage to improve the knowledge management capacity for future design processes by:

- Understanding the changing context of health care delivery
- Influence the strategic concept
- Lead and collaborate effectively
- Focus on users and flexibility
- Learn from research and past experience (further reading: See appendix 2)

5.2 Conclusions

Considering the knowledge management aspects addressed and triggered by the various tools and know-how developed within STREAMER and mapped on the RIBA stages, our analyses show that the developed components primarily meet the aspects of tools, and procedures. Less attention is addressed to the area of physical settings and social practice. This may be explained by the novelty of the techniques and tools and that these have yet not reached the gross of professional users in the building design and construction process.

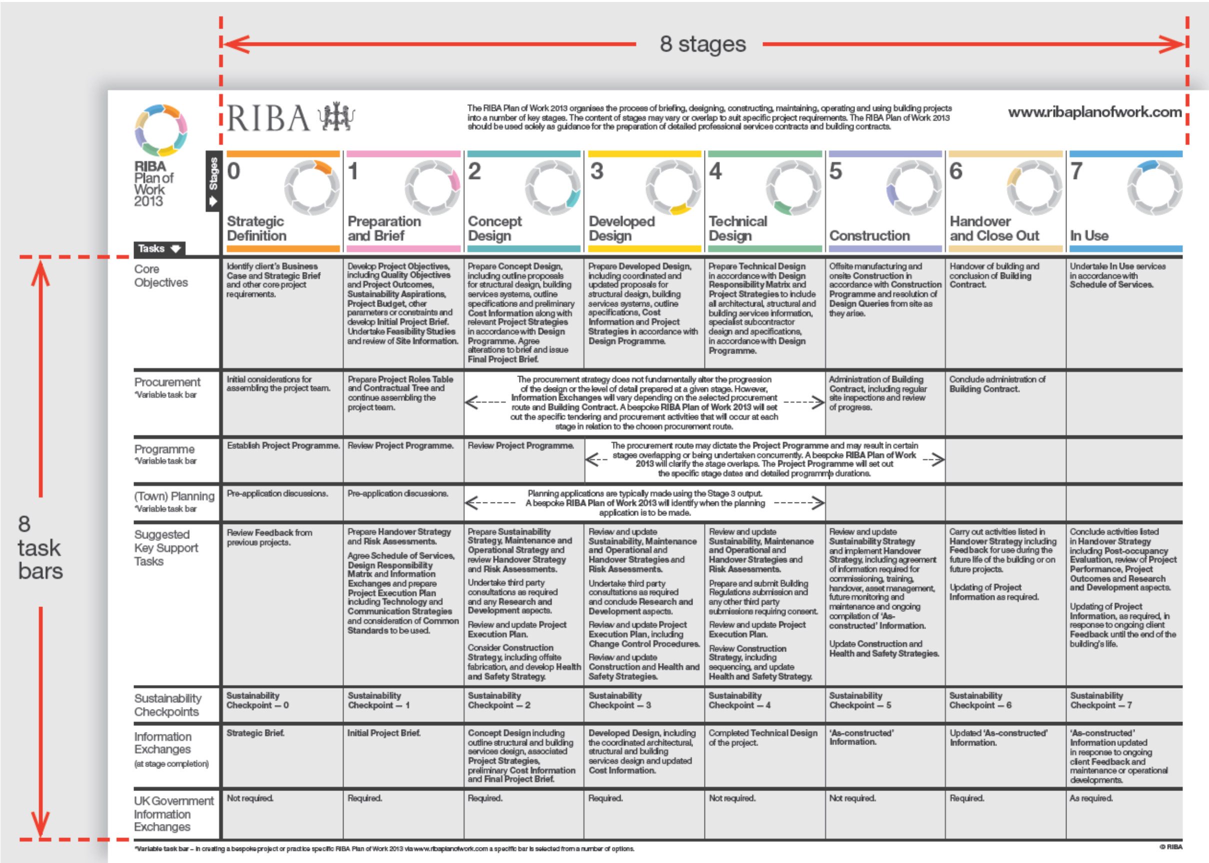
One way to deal with this identified shortcoming is by validating the tools that have been developed in STREAMER in the so called design workshops, held in four of the partner countries (IT, FR, UK and NL).

On the other hand, the wider application and further experience with the tools / knowledge of STREAMER in the daily practice of healthcare designing and construction is to come in the future, and just a matter of time. In a couple of years, we should be able to determine which of the STREAMER elements that have been developed have made it to become part of the social practice, and really land in the real life setting of architects, clients and other stakeholders working together on the design of an energy optimal healthcare district.

5.2.1 Key Recommendations for Knowledge management in the future

- A stronger focus on social practice and physical settings is crucial to make the knowledge flow and management of relevant design know-how, and optimal use of design supporting tools and instruction developed within the realm of STREAMER work to their full potential.
- While the digitalization of construction is making new design solutions possible, it is important that not all focus is put on the technical aspects but that the need for change management is also addressed. Technology alone will not solve all of our challenges but must be used in interplay with knowledge and experience of different actors in the design and construction process.
- The proposed Knowledge Diamond has proven a valuable tool for examining different aspects of knowledge management and could successfully be applied at a very early stage in order fully exploit the benefits of the tools and technologies developed within the STREAMER project.
- It is important to understand that the proposed STREAMER methodology will not automatically decrease the time needed for the design stage but instead addresses two very important aspects namely increased quality (including the sustainability factor) and increased customer value. In many recent reports and studies, these two factors are pointed out as main factors for improving the productivity of the sector.
- The procurement stage and the contract format will determine how and if the STREAMER methodology can be applied. It is important to observe that STREAMER bases its proposed tools and technology on a very complicated and complex problem area. Thus, it will not be cost effective to apply it on simple projects with little complexity. However, for health care district construction this is very seldom the case.
- Introducing relevant competences at a very early stage is important for the success of the project. This is further discussed in D4.5.

APPENDIX 1 – RIBA Plan of Work



Tasks	0 Strategic Definition	1 Preparation and Brief	2 Concept Design	3 Developed Design	4 Technical Design	5 Construction	6 Handover and Close Out	7 In Use
Core Objectives	Identify client's Business Case and Strategic Brief and other core project requirements.	Develop Project Objectives, including Quality Objectives and Project Outcomes, Sustainability Aspirations, Project Budget, other parameters or constraints and develop Initial Project Brief. Undertake Feasibility Studies and review of Site Information.	Prepare Concept Design, including outline proposals for structural design, building services systems, outline specifications and preliminary Cost Information along with relevant Project Strategies in accordance with Design Programme. Agree alterations to brief and issue Final Project Brief.	Prepare Developed Design, including coordinated and updated proposals for structural design, building services systems, outline specifications, Cost Information and Project Strategies in accordance with Design Programme.	Prepare Technical Design in accordance with Design Responsibility Matrix and Project Strategies to include all architectural, structural and building services information, specialist subcontractor design and specifications, in accordance with Design Programme.	Offsite manufacturing and onsite Construction in accordance with Construction Programme and resolution of Design Queries from site as they arise.	Handover of building and conclusion of Building Contract.	Undertake In Use services in accordance with Schedule of Services.
Procurement *Variable task bar	Initial considerations for assembling the project team.	Prepare Project Roles Table and Contractual Tree and continue assembling the project team.	The procurement strategy does not fundamentally alter the progression of the design or the level of detail prepared at a given stage. However, Information Exchanges will vary depending on the selected procurement route and Building Contract. A bespoke RIBA Plan of Work 2013 will set out the specific tendering and procurement activities that will occur at each stage in relation to the chosen procurement route.			Administration of Building Contract, including regular site inspections and review of progress.	Conclude administration of Building Contract.	
Programme *Variable task bar	Establish Project Programme.	Review Project Programme.	Review Project Programme.	The procurement route may dictate the Project Programme and may result in certain stages overlapping or being undertaken concurrently. A bespoke RIBA Plan of Work 2013 will clarify the stage overlaps. The Project Programme will set out the specific stage dates and detailed programme durations.				
(Town) Planning *Variable task bar	Pre-application discussions.	Pre-application discussions.	Planning applications are typically made using the Stage 3 output. A bespoke RIBA Plan of Work 2013 will identify when the planning application is to be made.					
Suggested Key Support Tasks	Review Feedback from previous projects.	Prepare Handover Strategy and Risk Assessments. Agree Schedule of Services, Design Responsibility Matrix and Information Exchanges and prepare Project Execution Plan including Technology and Communication Strategies and consideration of Common Standards to be used.	Prepare Sustainability Strategy, Maintenance and Operational Strategy and review Handover Strategy and Risk Assessments. Undertake third party consultations as required and any Research and Development aspects. Review and update Project Execution Plan. Consider Construction Strategy, including offsite fabrication, and develop Health and Safety Strategy.	Review and update Sustainability, Maintenance and Operational and Handover Strategies and Risk Assessments. Undertake third party consultations as required and conclude Research and Development aspects. Review and update Project Execution Plan, including Change Control Procedures. Review and update Construction and Health and Safety Strategies.	Review and update Sustainability, Maintenance and Operational and Handover Strategies and Risk Assessments. Prepare and submit Building Regulations submission and any other third party submissions requiring consent. Review and update Project Execution Plan. Review Construction Strategy, including sequencing, and update Health and Safety Strategy.	Review and update Sustainability Strategy and implement Handover Strategy, including agreement of information required for commissioning, training, handover, asset management, future monitoring and maintenance and ongoing compilation of 'As-constructed' Information. Update Construction and Health and Safety Strategies.	Carry out activities listed in Handover Strategy including Feedback for use during the future life of the building or on future projects. Updating of Project Information as required.	Conclude activities listed in Handover Strategy including Post-occupancy Evaluation, review of Project Performance, Project Outcomes and Research and Development aspects. Updating of Project Information, as required, in response to ongoing client Feedback until the end of the building's life.
Sustainability Checkpoints	Sustainability Checkpoint — 0	Sustainability Checkpoint — 1	Sustainability Checkpoint — 2	Sustainability Checkpoint — 3	Sustainability Checkpoint — 4	Sustainability Checkpoint — 5	Sustainability Checkpoint — 6	Sustainability Checkpoint — 7
Information Exchanges (at stage completion)	Strategic Brief.	Initial Project Brief.	Concept Design including outline structural and building services design, associated Project Strategies, preliminary Cost Information and Final Project Brief.	Developed Design, including the coordinated architectural, structural and building services design and updated Cost Information.	Completed Technical Design of the project.	'As-constructed' Information.	Updated 'As-constructed' Information.	'As-constructed' Information updated in response to ongoing client Feedback and maintenance or operational developments.
UK Government Information Exchanges	Not required.	Required.	Required.	Required.	Not required.	Not required.	Required.	As required.

*Variable task bar – In creating a bespoke project or practice specific RIBA Plan of Work 2013 via www.ribaplanofwork.com a specific bar is selected from a number of options.

© RIBA

Figure 10: Overview of RIBA stages in the Plan of Work 2013

APPENDIX 2 – RIBA for Healthcare Clients

"Many trusts lack the expertise to engage with the commercial development world, thus leaving them vulnerable to signing up to contracts that fail to generate the real benefits, both financial and clinical, that are available to them."
Planning crucial to future of the NHS Estate, Andrew Simpson, *Building Better Healthcare* (April 2015)

Problems with some of the newer estate include buildings: in the wrong place; that are surplus to requirement; that are rapidly becoming out of date as treatments and care change; that are over-specified and inflexible, making them expensive to operate and reconfigure; with a low residual or alternative value compared with their initial costs, making them relatively expensive to finance and difficult to dispose of. There is potential to: reduce the overall cost of the estate and improve the efficiency with which it is used; improve the appropriateness and quality of the environment for patients and staff; develop much more environmentally sustainable buildings and services; create collateral for new sources of finance; generate income from property rather than create one-off windfalls from sales - particularly when the property market is flat.

The UK National Health Service faces severe demographic, epidemiological and economic challenges in the years ahead. The complicated interplay between them calls for a revolution in how the NHS uses its estate. Far from constructing new buildings, the strategic focus is on divesting redundant holdings and in squeezing the remaining estate for optimum value.

Clients in the sector think that architects are equipped with many skills that could and should help in that strategy. However, they also acknowledge the significant structural barriers to their doing so. These include resource constraints, inflexible procurement routes, a disconnect between capital and operating costs, and a background of ever-evolving care models that make new designs difficult to brief successfully.

The need to comply with out-of-date standards - Health Technical Memoranda and Health Building Notes - stands in the way of useful innovation and design creativity. However, no such innovation or creativity is likely to be accepted without a credible evidence base of the kind championed by, for example, Architects for Health and ProCure21+. In that sense, although prior experience of working in the sector is not essential, it certainly helps.

UNDERSTAND THE CHANGING CONTEXT OF HEALTH CARE DELIVERY

Challenge
Health care delivery is facing numerous challenges, including a growing, ageing population, a higher incidence of chronic non-communicable and lifestyle diseases, and budgetary restrictions. As the policy imperative switches from cure to prevention and technological advances continue to affect clinical care models, the risk of building stranded assets grows.

Opportunity
Architects who understand not just the clinical strategy in a particular building but the deeply interconnected pressures, influences and trends in the sector as a whole are more likely to avert mistakes and interpret their clients' aspirations successfully.

INFLUENCE THE STRATEGIC CONCEPT

Challenge
Red tape, ponderous procurement routes, distance from the often multi-headed client and other barriers are part of an NHS super tanker that cannot easily be turned around even when there are known dangers ahead. They conspire to reduce opportunities to influence the strategic concept for any new building work.

Opportunity
Regardless of the procurement route, architects are encouraged to flag warnings and propose new directions at every opportunity so that the super tanker can avoid being dashed on the rocks of redundancy. In such a complex, uncertain system, however, a firm hand on the wheel is not enough. Slowing the engine, lightening the load and knowing what other dangers are nearby is equally important, to say nothing of coordinating the crew to better effect.

LEAD AND COLLABORATE EFFECTIVELY

Challenge
NHS Construction clients are typically inexperienced, multi-headed and caught in a tangled web of conflicting priorities. Once a commission is under way they need leadership and mutually supportive collaboration from their projects teams if they are to cut a smooth path through to completion and end up with the building they need.

Opportunity
Although there are many consultants competing for the coordinating role, clients think that architects are well placed to provide it. This means having a clear vision for the project and convincing the contractor or head client that you have both the technical competence and people and communication skills to deliver.

FOCUS ON USERS AND FLEXIBILITY

Challenge
Ultimately, the success of health buildings is measured by how well they facilitate patient recovery, bolster staff morale, and continue to function over time.

Opportunity
In-depth iterative dialogue with an informed client and key user representatives is the most important determinant of success. In particular, focussing on the needs of staff as well as patients, is critical, since not only are they the key factor in getting better health outcomes, their salaries constitute a very substantial perennial operating cost. Beyond that, building in flexibility to accommodate future change flexibly extends the building's life, a capital cost that has the potential to pay rich downstream dividends.

LEARN FROM RESEARCH AND PAST EXPERIENCE

Challenge
The default basis for much health care building design is the Health Technical Memoranda and Health Building Notes. Although compliance with these de facto standards is likely to greenlight designs, there is a widespread acknowledgement that they are not fit for use and constrain the kind of creative strategic thinking needed to answer today's pressing health care design questions.

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(source: https://www.architecture.com/RIBA/Professionalsupport/RIBAforclients/HealthcareClients.aspx)