Final report on the technical supervision and the quality assurance control

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Executive summary

The DREEAM approach aims at reaching energy savings of 75% in building energy consumption. To reach such an ambitious goal it is essential that the renovation works are performed correctly, therefore there is a need for a quality assurance system. This work is part of WP3, the demonstration part of the project, and most specifically part of Task 3.3 “Technical supervision”, in which RISE performed monitoring through quality checks during the construction process for each demonstration site, based on the experience gained within the SQUARE project and on its own systems for moisture-proof, airtight and energy efficient building (ByggaL, ByggaF, ByggaE).

This report is about the planned implementation of RISE’s quality system into a digitalised, user-friendly tool to be used onsite by the supervisors and construction workers, using Strusoft’s extensive experience in software and digitalisation of the built environment, with the ambition of integrating such a tool into their own building information system (BIM) products.

The deliverable starts from the lessons learned in the project, then gives a panoramic of RISE’s quality system and its current applications in Sweden and ends with sketching a possible way of implementing the concept together with Strusoft, with concrete plans which have been made to make a joint application for funding in other national and European projects to pursue the implementation of the digital tool.

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1 Lessons learned in the DREEAM project

The idea when the proposal was written was to implement some of RISE's own quality assurance system, ByggaE, ByggaF and ByggaL (which are concerned with the performance of the building in energy efficiency, moisture safety and air tightness respectively), into the quality systems of the building owners of the demonstration sites, just for the implementation period of the renovation works.

This idea, which looked good on paper, proved to be too hard to implement in practice and it would have impacted negatively on the projects, for the following reasons:

- A quality assurance system (QAS) is a complex structure of documents, routines and procedures and every change in one part has the potential to cause change in other parts of the system, due to the nature of checks and follow-ups that often depend on each other. Therefore, the modification of the procedures concerning the implementation phase would have affected other aspects of the system, going beyond the boundaries supposed in the DoW (Description of Works) (such as the maintenance and the operational phase). For example, when a check is required on the execution of a seal, its performance will have to be periodically controlled after the construction phase is over, during the management one;
- Implementing a QAS is time and resource intensive task, and the resources allocated for WP3 would not have been enough to allow implementation of RISE's QAS in three different QASs, one for each of the three pilot sites, since the three site visits per site were already time consuming. This was underestimated in the DoW probably due to the fact that sometimes the research world is not aware of the challenges that the application of theory in practice would entail;
- The concept itself of quality assurance implies an approach from begin to end, from the design phase to the commissioning after the building has been built or renovated. Implementing a QAS just for a project phase, whatever the particular system, is not worth the effort. It is much better to plan the implementation of a whole QAS, which will bring higher return for the invested work;
- The delays in WP2 which affected WP3 reduced the time in between the definition of the renovation solution packages and the start of the works, the period during which the QAS should have been defined (since it was about the implementation phase, it would have had to be defined accordingly to the renovation strategy to tailor it to the pilot site);
- An additional level of complexity was the fact that contractors operate their own QAS which in some cases would have been specified in the tender for the works and may actually have been the standard QAS used by the building owner;
- The building owners, for understandable reasons, were not very excited about the implementation of a QAS, due to the extra amount of time and effort that would have been required from their side to integrate the "foreign" QAS into their own audits, meetings, negotiations, consultations, and so on. It would have involved a lot of effort to discuss how to proceed, which parts of the QAS to use and which not, and prepare all the additional necessary paperwork;
- The different work culture in the pilot sites (in England, Germany and Italy) made it necessary to adapt the structure and format of the QAS to the specific case: the *ByggaX* are created with the

Scandinavian work culture in mind, where the single worker has a great degree of responsibility and freedom in his or her daily work and can therefore perform most of the checks himself, while the Mediterranean work culture is more hierarchical and relies on constant supervision and reporting to the manager or superior;

For these reasons, it was decided together with the Project Management and building owners to go for a compromise: RISE's personnel performed the quality assurance checks during the planned site visits, leaving feedback for the building owners and reporting the results in the deliverables 3.4, 3.5 and 3.7. By doing so it was possible to learn from each other, about the different ways of working and how quality assurance is perceived and implemented.

In the light of the lessons learned in the DREEAM project, whenever a QAS is to be implemented, the following actions are advised:

- Plan the resources taking into account a great effort from the building owners' side, which will be almost as much as the effort which is necessary from the partner in charge of introducing the QAS. Plan for a certain number of periodic meetings to discuss the work and how to proceed: this will be a lengthy process, the more complex the building owner's quality system the longer and more time-consuming the process will be;
- The company responsible for the QAS should have a good understanding of both the existing QAS that will be modified and of the work culture in that country, to ensure the smoothest integration possible. Some help from the building owner could be required, and maybe a visit to the workplace so this has to be planned accordingly as well;
- Inform the building owners when writing the proposal about how demanding such a process it will be, but also about the benefits it will bring, especially if they do not own a comprehensive QAS beforehand, to ensure commitment if the project becomes reality. A good idea would be to put in contact the Quality Manager of the building owners' company (or with an appropriate Project Manager or supervisor) and the people in charge from the other side, so that some technical arrangements can be made prior to the start of the project, also to determine in which direction to steer the work and what are the limitations;
- Do not limit the quality assessment only to the implementation phase, but to the whole project's course, given the amount of work that will have to be invested anyway. If this is not possible, consider finding an alternative solution such as entrusting the quality assessment to a partner, as was done in the DREEAM project.

2 Needs of the built environment concerning quality assurance

During the course of the DREEAM project we have identified some needs that are peculiar to the built environment when it comes to the key points of energy, moisture and air tightness, and to the process-specific quality assurance.

2.1 Needs for an energy-efficient, moisture-safe and airtight construction of buildings

For more insight into the subdivision of the three main topics of interest (Energy, moisture and air tightness), see D3.4 and D3.1. Below we discuss the present and future challenges that the built environment will face when it comes to addressing these topics.

- Energy: it is a challenge to follow up on the energy consumption and check if the goals set at the beginning of the project were reached. A well-devised quality assurance system makes it easier to see which requirements were met and which were not, also helping at the early stages by helping to define the very goals and requirements according to the existing laws and the targets of the building owner. In the last 10 years the requirements on energy consumption have been tightened a lot in terms of kWh/m^2, so a careful planning is required as well as a follow-up to ensure targeted consumption is met.
- Moisture: one of the most crucial and yet overlooked points is how to manage rainfall and moisture pentration. Many moisture sensitive materials like wood have exceptional building properties and they are getting more and more popular now, but they need to be managed carefully during the construction phase, something often neglected especially in massive wood structures. Quality assurance is paramount so that the building will not be damaged by precipitation during construction. This can be done either by checking the moisture levels in the materials during construction or implementing a rain protection system. Building with fossil-free materials is on the rise therefore the need of this.
- Air tightness: the industry has made great steps in this direction, both on product development (particularly tape and sealing products) and design (more understanding about how it works and should be implemented), testing (competence, testing methods and routines). There is still a need for commitment from the project management, as air tightness must be focused on at all stages of construction as every construction phase can influence the following one, for example installing the air ducting can compromise the air tightness if sealing work is not done correctly.

2.2 Needs for quality assurance and processes

- Understand and manage better the different tender forms and adjust the quality system accordingly. There used to be just two approached, either the building owner had little or no involvement in the building, hiring a construction firm that would take care of all the work (design and build), or it was the building owner that first called in an architect to set up the project and then the single contractors/consultants to erect the building or do the renovation. Now there are many tender forms with different allocations of responsilities and risks.

- One problem that is often encountered is that it is not clear who is responsible for the different work phases, which makes quality assessment more difficult. It should be evident in the QA who does what and who is responsible for it, so that it can be easy to follow up. The construction industry should work to better identify the actors at each stage.
- The quality assurance system should be able to go beyond the language barriers in the workspace, especially now that the contractors are often from abroad.
- The building sector is very traditional with practices very similar to those 50 years ago. In the future, harder requirements will be introduced on resource use and materials as well as building process, similar to what has happened with the car industry. In the last 10 years a lot has happened in the digitalisation of cars and in the fuel choice, with the advent of electric cars and alternative fuels including biofuels. With those changes, a lot of quality related questions will come up, such as the resistance of materials, testing, and so on especially in regard to moisture ingress. Simulations, both in terms of energy and moisture calculations, will assume a growing relevance and therefore there is a need to integrate them in the quality assessment process at the right moment.

2.3 The DREEAM quality assurance system

The quality assurance system, the *Bygga* series that was developed by RISE and implemented, at least on paper, for the implementation phase of the renovation in the framework of the DREEAM project, has the following features that will help the stakeholders to reach the goals concerning the energy consumption and sustainability of the renovation or construction projects.

- Support to manage the QA. The *Bygga* system specifies responsibilities and clarifies the process, by identifying which requirements are to be followed and which person is in charge for each control or building phase. A further planned development of the RISE QA will make it possible to connect with other tools, such as simulation programs. For example: *ByggaE* makes sure that the energy simulations are done in the right phase and the right actions are made to address any problems or values that are not good enough for the requirements.
- Communication between the different building phases. By implementing the DREEAM QA in a project, continuous feedback and communication between the actors involved in the construction/renovation process (such as between the plumbers and the carpenters) is provided. This helps achieve overall better project results.
- Also, QA is no simply the responsibility of one person, but all the actors (from the project manager to the construction workers) have to be involved. To reach the right people it is necessary to have a digital version, it is impossible that everyone in the project knows the whole QA but it is important to make sure that the right information reaches the right person. A digital version would make it very easy for workers to know exactly what he or she needs to check or which critical points are actually at a certain stage or at a certain work task.

3 Quality assurance within the DREEAM project

As explained above, the DREEAM QA system that was based on RISE's own *Bygga* system was not implemented into the specific QA systems used by the building owners. Instead, the RISE personnel carried out the quality assurance themselves by visiting the demonstration sites three times, namely at the beginning, middle and end of the renovation process.

The site visits were performed as follows:

	First visit	Second visit	Third visit
Berlin	January 15th 2018	September 20th 2018	June 18th 2019
Padiham	February 12th 2018	September 13th 2018	July 3rd 2019
Treviso	February 7th 2018	October 10-11th 2018	July 4th 2019

The quality assessment work that was performed is explained below. For the specific assessment of the renovation works done at the different sites, see the relevant deliverables about the site visits (D3.3 – First site visit, D3.5 – Second site visit, D3.7 – Final site visit).

- First site visit: before the visit, RISE's personnel collected information about the site (type of walls, windows, heating system, building services, ventilation, year of built and so on) and the renovation work that was planned to be done, through the support given in the tendering process or by asking the building owner directly such as in the Berlin site (as 1892 entered the project in a later phase). The first visit assessed the state of the buildings before the start of the renovation works, (through documentation and visual checks), and identified the critical moments that would have required special care during the renovation process for every site.
- Second site visit: this was performed during the renovation period, when the works were about halfway through. The visit consisted of assessing how the installations and works were being carried out (random checks were carried out, which means that not all windows were checked, for instance), to see if the procedure was correct and if there was some defect that would have been detrimental to the energy performance, moisture safety or air tightness of the building, these being the three aspects important for the overall quality of the renovation. Feedback was left for the building owners, specifying the necessary improvements to be carried out to guarantee the desired standard and reach the goals of energy efficiency set at the beginning of the project. It was about checking the critical points identified during the first site visit and to add new in case it was necessary.
- Third site visit: this was performed at the end of the renovation works, to assess the overall quality of the work carried out. Once again, the checks were done randomly during the visit, the building owner showed the RISE personnel around and answered questions concerning the renovation process. The critical points in the checklist that were identified in the previous visit were reviewed and a final assessment was made. During the final site visit

the lessons learned in the renovation process as explained by the building owner were collected. This was not strictly relevant to the quality assessment but of importance for the broader perspective of replication and implementation in future projects.

Figure 1. Result of renovation works at Padiham, showing the difference between a privately owned, non-renovated house, (brick structure), and the renovated ones with external insulation.

4 A digital tool for quality assurance

As was explained in the previous deliverables, a quality assurance system includes a lot of documents, paperwork, templates, routines and folders. Even though the Bygga series is available online for download, it does not mean that there is a digital version (like an app or a program) of the QA system, but rather simply that the whole documentation is available. RISE and StruSoft started a collaboration to turn the QA system that was developed within the DREEAM project into a digital version, like an app, to ease the job of the construction worker or controller that goes around and does the quality checks onsite. This has the potential to be a commercial product.

4.1 Collaboration with StruSoft

StruSoft's commercial software comes in five applications – FEM-Design, IMPACT, VIP-Energy/BIM energy and BIM contact [1].

StruSoft also has experience in the research environment and is active in several Swedish and international projects, to stay at the forefront of innovation. To cite some apart from DREEAM; it participated in the EU 7th framework *Ecodistrict* project, which dealt with developing a design support tool for sustainable major urban retrofit of districts [2]. StruSoft was mainly responsible for the development of the software platform with focus on client interfaces, visualization and connection to energy simulation modules. They worked closely together with RISE (SP) in this project. Another example is *SAM – Smart Asset Management* (Vinnova) [3], which is about innovative IoT solutions to reduce energy consumption working together with energy companies. StruSoft works on visualization and monitoring technologies for data collection.

StruSoft realised the potential of the quality assurance system developed by RISE, and since it is being widely used in Sweden, it had the idea of turning it into a digital version to make its use even easier and therefore to increase the number of users and its diffusion in the Swedish market. The collaboration between RISE and StruSoft it is still in its early stages and at the time of writing this deliverable, we are identifying which national calls for proposals are available in Sweden that would suit the development of the tool. A promising one so far is from *IQ Samhällsbyggnad* in the framework of "Smart built environment", concerning digitalisation, that has been identified as "the single most significant change factor of our age" [4]. The strategic innovation programme (SIP) Smart Built Environment is a plan that outlines how the built environment sector can contribute to Sweden's journey to the global forefront of the new opportunities of digitalisation, so that we can achieve intelligent, sustainable cities, manage our resources more efficiently and reduce carbon emissions.

More opportunities through other research channels are currently being investigated as well to maximise the possibility of financing.

4.2 A digital quality assurance system

As has been explained in the previous deliverables, a QA system is a set of documents, folders, checklists and routines that have different formats. Some are in the form of Excel files, tables to be filled or normal Word or PDF documents to be read since they describe the procedure to be followed, for instance during the periodic meetings that will be hold at the workplace.

When the user downloads the documentation, he or she will see that it comprises a set of folders each one corresponding to a project phase, and sub-folders where relevant to distinguish the specific building systems and components (heating, cooling, ventilation, insulation, electrical system, lighting and so on). An example is shown in the picture below.

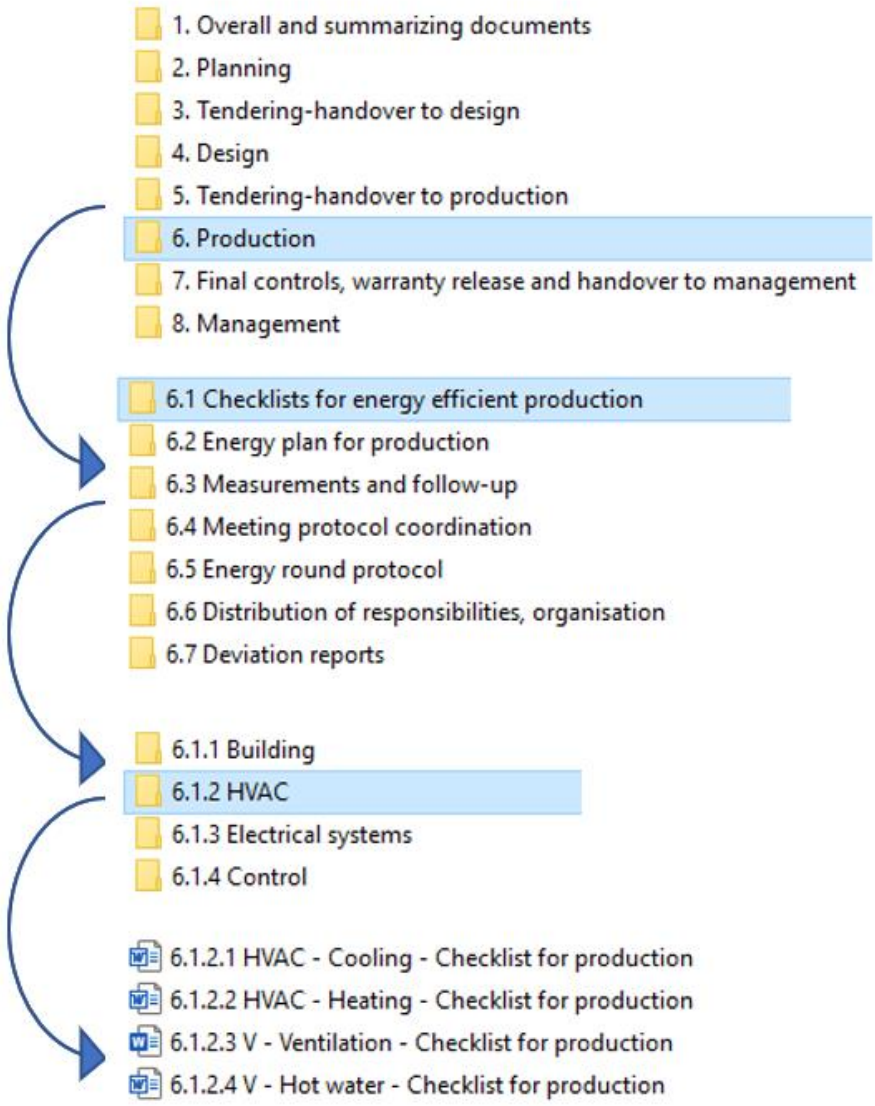

Figure 2. Folder system example in the DREEAM QA system.

Each folder has a set of checklists and instructions, that will have to be printed out and taken to the site during the inspection, which means relying on paper systems. The worker will then check the points on the list and make remarks and annotations, taking notes wherever there is something to be followed up. Taking pictures is also a possibility (for instance to identify a defect in the airtight sealing of the building envelope, wherever the membrane is missing, or the sealing was not performed correctly) for a better explanation and faster identification of the defect or point that needs to be fixed. This adds nonetheless an additional degree of complexity to the reporting since the picture has to be stored in the folder under a proper name, requiring the creation of a sub-folder corresponding to the specific site visit.

For instance, the figure below shows part of the checklist for the external wall. The right part is reserved for comments and signature to confirm that the check was done correctly. It has to be done by hand, or notes can be taken onsite and then the document can be filled in the digital version: this has the disadvantage of taking more time and being less accurate as some information can be lost as time passes between the visit and the filling of the document.

Building part:	Properties:	To take into account: Exemples on critical points, important moments etc A ticked square means that the point has been taken into account	Result Comments: Comments to performed controls Refer to documents where results, assessments etc. are presented. Is more follow-up needed?	Checked? Sign the check
External wall	Insulation	☐ Filling (light sheets are cut with an excess of 5-10 mm for good filling) ☐ Width of bought insulation suited for wooden or steel studs ☐ Joints ☐ Correct density ☐ Correct installation, fiber orientation ☐ Termography	Comments: Reference:	☐ Yes ☐ No What? When?
		☐ Thermal bridges: • Windows installation • Doors installation • Perforations • Bearing frame • Floor slab connections with walls • Balconies fastening • Shaft • Sheets in the construction • Filling of insulation material (compare mineral wool - cellular plastic)	Comments: Reference:	☐ Yes ☐ No What? When?
		☐ Installation of windbreak, joints, connections and perforations. Pay attention also to water diversion function. ☐ Risk for water permanence and its influence on the insulation properties ☐ Natural convection	Comments: Reference:	☐ Yes ☐ No What? When?

Figure 3. Checklist for external wall

The concept is to make a digital version of the system, eliminating the need for printing of the documents as everything will be available online or in an app that the worker will have installed into the smartphone or tablet.

4.2.1 Features of the digital version

This is still a work in progress, but most of the features that the digital version will offer have already been identified and are listed and explained below:

- Have a user-friendly interface: this is a crucial point since the success of the tool will depend on how easy it will be to navigate through the different folders and how quickly it will possible to find the documents needed by the user. StruSoft has a long experience not only in software but also in interface and visualisation, which will contribute to creating a functional digital version of the DREEAM QA system.
- Automatic storage of information: when the user fills in the checklists, the system stores it automatically at the right place, so that there is no need for the user to know exactly in which folder the document has to be saved.

- Possibility of taking pictures: this is probably the most important and useful feature of the digital version. The user will be allowed to take pictures through the camera of the smartphone or the tablet, and the pictures will be saved as attachment for the specific checklist point. This will make it easier to describe the specific point, and it will be immediately available to the other workers involved in the project so that they will not have to just rely on a written description, but they will be able to see the building component themselves.
- Instruction manual availability: the digital version will need to have a digital manual / help system to guide the less experienced user during the field visits that can be checked anytime, making it a valuable addition to the QA.
- Possibility of exporting and sharing: with digitalisation comes the opportunity of sharing the documents, as well as editing, and saving in a common space so that the building management or other actors not directly involved in the process would be able to see what it has been done and follow the quality assurance process. This also facilitates audit of the QA process itself.
- Possibility of tracking work progress: it will be possible to know at a glance which stage the project is in and if the project is following the timeline.

4.2.2 Advantages of the digital version

- Less to no paper documents: since everything will be digitalised, there will be no need for printed documents, binders and so on. This will result in a saving of resources and more importantly keep information in a more organised, time-saving structure.
- Easier communication between actors: since everything will be cloud-based, the relevant information will be available automatically to each stakeholder and specific messages can be sent to the relevant person (for instance if there is some cabling to fix, the electricians can receive a notification to carry out the work).
- Correct placement of information: there will be no need for the user to think about where to physically place the paper document or where to save the updated file since everything will be done automatically by the system.
- Online access to the documentation: the involved actors will be able to access the whole documentation at all times from anywhere, through login credentials and a password. This means that even though the project manager is not at the office, it will still be possible to check the work progress.

4.3 Further developments

The greatest potential of having a digitalised QA system lies in the possibility of connecting it to a Building Information Modelling system (BIM). This would mean that the quality assessment aspects would be embedded into the specific building blueprints, therefore highlighting the critical moments linked to renovation/construction. Every intervention made on the building, every check would be registered on a deeper level allowing the project manager a total understanding of the situation.

A BIM system is very complicated in itself, and the present ones are still not very user friendly. Adding a level of complexity by inserting another layer, the quality assurance system, would be too much of a tall order for the time being and the available resources, but it its implementation will be investigated further as the QA system is successfully digitalised.

5 References

[1] https://www.strusoft.com

[2] https://ecodistr-ict.eu/

[3] https://www.vinnova.se/p/smart-asset-management---sam/

[4] https://www.smartbuilt.se/in-english/