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Risk management in procurement of blue-green roofs – supplier perspective

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Abstract. Blue-green roofs are increasingly adopted as a measure to reduce risk related to stormwater events. However, as a novel building element they present elements of uncertainty in themselves. The integrity of the roof is vitally important to long-term building operation, it is therefore important to understand the extent and impacts of this uncertainty. Documents from building product suppliers are investigated to chart how technical uncertainty and quality risk is managed regarding blue-green roofs. The main form of uncertainty management comes in the form of performance declarations, specifying the operating limits of the products. If a failure occurs, the supplier seeks to be able to document that the quality of the product was not at fault. The processes by which product performance is documented may be very challenging for anybody but the suppliers themselves to gain insight into.

Keywords: Blue-Green Roof, Risk, Uncertainty Management, Supplier Perspective, Quality

1 Introduction

A blue-green roof is a roof assembly in which plants and water-detaining sub-layers are used to temporarily store rainwater, delaying stormwater runoff from the roof. Even though all green roofs have some capacity to detain water, the "blue-green" moniker is usually reserved for cases where the roof assembly is explicitly used for stormwater management purposes[1].

In Norway, climate is changing to become milder and wetter. In particular, intense precipitation events are expected to become more frequent and more intense, increasing the risk of urban flooding [2]. Data from Finance Norway [3] shows that insurance payouts for damage incurred by weather events more than doubled in ten years. Measures to mitigate the risks posed by intense precipitation and stormwater events are becoming ever more necessary.

The Norwegian sewage system is found to be in poor and deteriorating condition. The total cost to upgrade it to a satisfactory condition is estimated to be around NOK 110 billion [4]. This undertaking would be prohibitively expensive, and does not factor in the cost of capacity upgrades. Therefore, it is unfeasible to address the challenges posed by future stormwater events through the sewage system alone. Local solutions for stormwater retention and detention are required. Blue-green roofs are found to be effective in retaining and detaining stormwater, making it a feasible risk mitigation measure even in cold and wet regions [5].

However, while blue-green roofs can be a risk reduction measure from some perspectives, they also introduce a certain degree of risk in themselves. Blue-green roof assemblies are mounted on top of conventional compact roofs, adding additional layers to a building's outer envelope. This addition changes the physical boundary conditions of the extant roof, and covers the watertight roof membrane whose long-term integrity is vital for avoiding water damage to the construction underneath. These changes introduce elements of uncertainty that have to be investigated thoroughly, in order to chart and minimize the eventual negative consequences of adopting blue-green roofs on a large scale.

The terms risk and uncertainty can be understood on many different levels, and from the perspective of many different actors. In order to present a suitable level of detail within the practical constraints of this article, it is decided to limit its scope to the technical level and to the perspective of the product supplier. Additionally, it is decided to focus on the procurement phase. This article aims to investigate how uncertainties related to the building's quality is handled in practice. The study is limited to the procurement phase and from the suppliers perspective. The following research questions are examined:

1. What challenges and risks do product suppliers face related to green and blue-green roofs?
2. What strategies are applied by product supplier to control and manage risk related to green roofs in the procurement phase?
3. What improvements can be made?

The research is performed as a desktop study, by examining documents from the design and procurement phase of construction projects featuring green roofs. It is investigated how construction product suppliers in Norway address technical uncertainties in their involvement in construction projects.

2 Theory

2.1 Green and blue-green roofs

Blue-green roofs are green roofs specifically designed and used to function as a stormwater management measure[1]. Like other green roofs, they exist either as *extensive* assemblies, where Sedum plants grow on a thin mat of substrate; or *intensive* assemblies with significantly thicker substrate layers, allowing lawns or even parks with trees to be planted on building roofs. Extensive green roofs are usually not meant for traffic, while intensive green roofs can be robust enough to allow vehicles to drive on them. A principle schematic of a blue-green roof assembly on a compact, flat roof is shown in **Figure 1**.

A primary function of a blue-green roof is to retain stormwater (storing it in the roof assembly until it evaporates) or detain it (delay runoff), reducing the load on local stormwater drains by eliminating or reducing roof runoff. However, the key purpose of a roof is to provide a weather-tight cover for the building, a function that must not be compromised. The Norwegian building regulations specifically stipulate that water leakages must not occur [6].

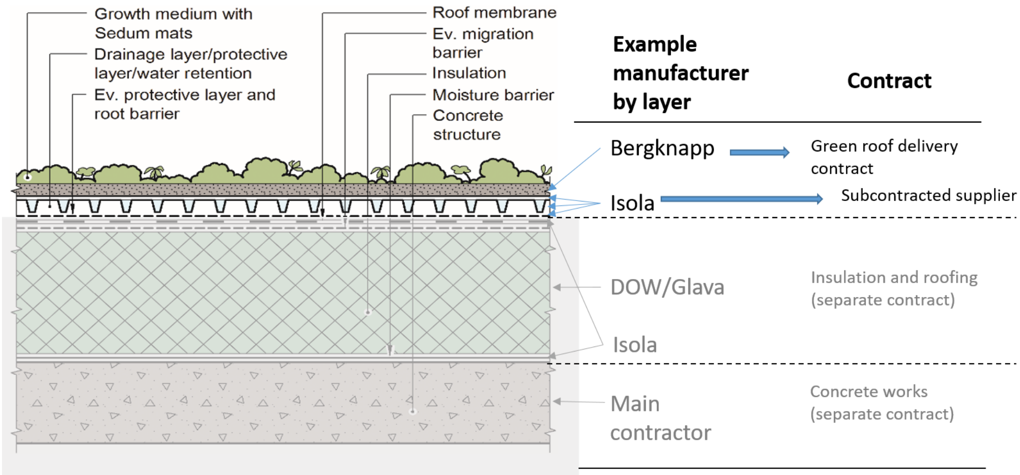

Figure 1: Principle of a blue-green roof assembly on a compact flat roof, as well as examples of delivery contracts involved in its assembly and their product suppliers. Figure adapted from [7].

2.2 Failure modes of blue-green roofs

Conceptually, a blue-green roof can fail in two ways: It may fail to deliver the stormwater management capacity that was requested or lose its capacity over time (performance failure); or it may suffer a defect that compromises the integrity of the roof assembly (quality failure). The latter failure mode generally has more serious ramifications for the long-term operation of the building than the former, and will receive the point of focus in this article.

Quality failures can generally be divided into three categories: Product failures, design failures or assembly failures. With this article focusing mainly on the suppliers, product failures will be most relevant in this case, although unclear or incorrect information from suppliers may be a contributing factor in design or assembly failures as well. Determining the exact cause of a roof defect may often be challenging, and several parties may share the responsibility.

2.3 Uncertainty management strategies

The term “uncertainty” within a project context is usually understood as “an event that, if it occurs, has a positive or negative effect on a project’s objectives” [8]. This definition includes risk when the outcome of uncertainity is negative, and opportunities when the outcome is positive. To manage opportunities, strategies as share, exploit, accept and enhance could be chosen, while when managing risks strategies like avoid, reduce, share and accept could be chosen [9]. Different uncertainty management strategies could be chosen, based on whether risk or opportunity is considered, or based on the type of uncertainty [8]. Uncertainty management strategies should include both proactive, interactive and reactive ways of thinking [8]. Uncertainty management would also depend on one's perspective in the project.

From the supplier's perspective, the main risk related to blue-green roofs is to be declared responsible when a roof fails, and having to pay for repairs or replacements. A major priority will therefore be to specify a given quality level for their products, so it can be determined as accurately as possible the circumstances in which they are suitable. If the product is used in an unsuitable fashion, or its declared operating parameters are exceeded, *and* the relevant information was made available to designers and contractors, the supplier is less likely to be considered at fault for the failure, following [6,10].

2.4 Phases of a construction project

Figure 2 shows the phases of a construction project, as well as the hierarchies involved in the construction process. The main focus in this article is on the design and construction phase, and from the supplier's perspective.

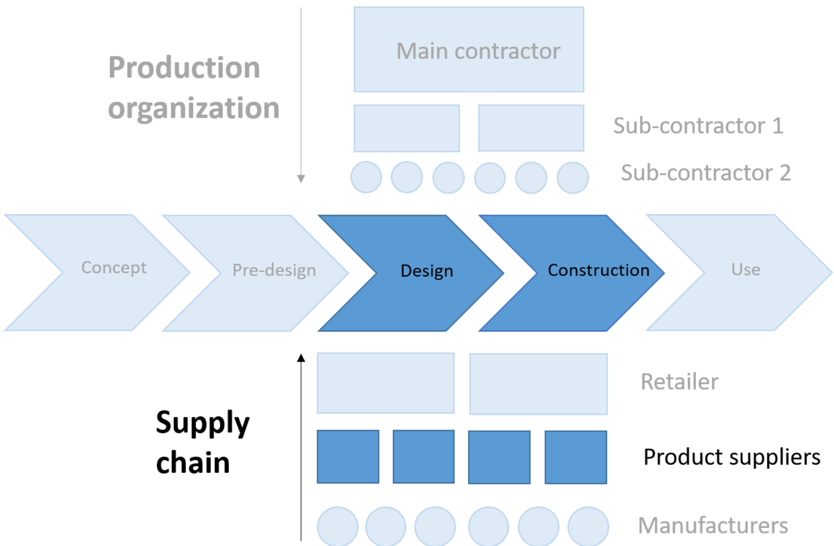

Figure 2: Principle sketch of main actors in the production organization and supply chain of a construction project. The illustration is principal in nature and does not cover actual real-life processes. Highlighted parts illustrate the scope of this article.

2.5 Knowledge gap

Although a significant body of literature could be found on the subect of uncertainty management, the authors of this paper have not identified significant research literature on the management of risk from the supplier side. It remains uncharted what measures suppliers take to minimize quality risk or their exposure to it.

3 Method

This being a desk-top study, a literature study was performed to gain insight on the composition of blue-green roofs and their common failure modes [1]. The study was performed as a scoping study, retrieving 100 research articles for analysis. For this article, the results of the literature study have been used to write the Theory section. Uncertainty management literature was identified through literature review, and searched for uncertainty management from the supplier perspective. Much literature was found from the project owner' perspective, some from the contractor's perspective, but none from the supplier's perspective.

In a desktop study, the websites of suppliers of products used in blue-green roofs were examined, to map what measures the suppliers take to mitigate risks. Products available on the commercial market were studied through datasheets, assembly instructions and, if available, technical certification. Documents were retrieved both from supplier websites and the websites of a certifying body, SINTEF Certification [11].

4 Results

4.1 Declaration of performance

Product failures occur when operating conditions exceed the performance limits of the material. Suppliers will therefore need to chart the performance limits of their products as accurately as possible, so it can be formally declared under which conditions their product will perform as advertised.

Performance is declared based on tests following procedures codified in industry standards. This ensures that all products are tested with the same criteria under the same conditions. Each product category may have dozens of associated testing standards; for instance, the standard NS-EN 13707:2013 for definitions and characteristics concerning flexible reinforced bitumen sheets for roof waterproofing [12] lists 23 other EN and ISO standards as "indispensable for its application".

Suppliers provide a declaration of performance for each of their products, listing the vital properties of the product and the standards used to determine these. Examples of such properties and declarations are given in **Table 1**.

Table 1: Example of declared properties and standards used for products in blue-green roofs

Product	**Isola Rotmembran (Roof membrane/root barrier)**	**Protan Titanium+ (roof membrane)**

Declared properties and standards	Root resistance	EN 13948 FLL	Essential characteristics	EN 13956:2012
	Dimensional stability	EN 1107-1	External fire performance	EN 13501-5
	Reaction to fire	EN 13505-1	Reaction to fire	EN 13501-1
	Watertighthness	EN 1928	Water tightness	EN 1928(A)
	Tensile strength	EN 12331-1	Tensile strength	EN 12311-2(A)
	Tear strength	EN 12310-1	Resistance to impact	EN 12691(A)
	Flexibility at low temperature	EN 1109	Resistance to static load	EN 12370(C)
			Tear resistance	EN 12310-2
			Joint peel resistance	EN 12316-2
			Joint shear resistance	EN 12317-2
			Foldability at low temp	EN 495-5
			Exposure to UV	EN 1297
			Root resistance	EN 13948 FLL

The multitude of relevant testing standards ensure that the relevant properties of the products may be determined according to standardized procedures. However, it may still be very challenging for the actors further down the supply chain to obtain a clear overview of the properties of the products. Knowing the parameters of the tests requires familiarity with the relevant standards, of which many exist for every product category. Gaining access to the full text of each standard is also fairly expensive, further limiting the designers or contractors from becoming familiar with the procedures by which the products are tested. Realistically, the persons responsible for design or assembly may not be familiar with the testing standards for more than a handful of products, increasing the risk of design or assembly failures.

4.2 Technical approvals

Suppliers may enlist a third party controlling and verifying the performance of the product and its suitability for use. Certification bodies such as SINTEF (Norway), RISE (Sweden), BBA (UK) and TÜV (Germany) offer independent controls and certifications of the performance of the product in question, as well as assessments of whether the product is suitable for its intended use. Use of certifications is voluntary, but it is found to be a common practice in the Norwegian building sector to manage risk by requesting a certificate of approval from such governing bodies for all construction materials used in their project, which implies that certification is practically a requirement for a product to be competitive on the market.

4.3 Assembly/use instructions

A construction product is often highly specialized for one purpose and may be unsuitable if used in different contexts than it is designed for. For instance, a root barrier used to protect the roof membrane underneath a green roof may deteriorate quickly if not covered by a green roof assembly, since it is not designed to withstand solar radiation. To prevent product failure caused by faulty use or application, suppliers inform about the product’s intended use condition in product datasheets. Relevant information on storage and assembly is also applied; in some cases a separate, detailed assembly instruction is provided as well.

5 Discussion

This article seeks to answer the following research questions: What challenges and risks product suppliers face related to green and blue-green roofs, what strategies are applied by product supplier to control and manage the risk, and what improvements can be made.

Quality failures related to green and blue-green roofs can generally be divided into three categories: Product failures, design failures or assembly failures. The supplier could be responsible for product failiures, and the main risk from the supplier's perspective is being declared responsible and having to pay the costs incurred. There are many sources of roof failures, including poor workmanship and poor design in addition to product failures. Poor workmanship and poor design may also stem from a lack of knowledge about correct use of the products, which the supplier may be declared responsible for if the provided information is found to be insufficient.

With the main risk management strategies being to avoid, transfer, reduce or share risk, the supplier's best option is to reduce the risk related to product failiure. A proactive strategy is a must instead of interactive (handle risks as they happen) or reactive (fix after the damage has occurred). Risk is also transferred away from the supplier through detailed declarations of performance. If damages occur due to incorrect design or faulty assembly, where the stated performance parameters of the product were exceeded, the supplier will not be liable to pay compensation.

However, a certain challenge is posed by the relative obscurity of product standards by which the product's performance is determined. Designers or contractors may not be familiar with the limitations of the declarations, increasing the risk of design and assembly failures. Suggested improvements involve higher transparency in the product standards, with the goal to make actors further down the supply chain more familiar with the limitations of the standards (and therefore, the products). Further use of independent product certifications is another suggested measure, where the certifications include an assessment of the product's suitability for its intended use. These measures intend to set clear limitations about how the product is supposed to be used and how it will perform.

6 Conclusions

Quality risk appears to be a topic of concern for suppliers, although the key focus appears to be to avoid blame for failure rather than preventing failure in the first place. This is achieved through declaring specific limits of use for their products, both in terms of storage, assembly and operating conditions. The declarations of performance may also be verified by third parties. The methods by which the limits are determined are openly available through product standards. However, few actors involved in the construction process are fully familiar with the standards, and access to their full text is expensive. It may therefore be likely that the persons responsible for design and assembly will not have the required knowledge of the product's use parameters, increasing the risk of a design or assembly failure. Possible improvements identified through the research are increased use of third-party verification, clearer declarations of performance and proper use instructions, in combination with suppliers offering courses and training for the construction industry.

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