HERITAGE SIGNIFICANCE ASSESSMENTS TO EVALUATE RETROFIT IMPACTS: FROM HERITAGE VALUES TO CHARACTER-DEFINING ELEMENTS IN PRAXIS

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Abstract: Improving the energy performance of historic districts and their buildings is a balancing act between retaining their heritage significance and allowing the installation of retrofit measures. This paper describes a heritage impact assessment methodology to enable such a balancing process in a well-structured and systematic way. The methodology is one of six impact assessment modules for a decision support system, a software tool under development for the research project Energy Efficiency for EU Historic Districts' Sustainability (EFFESUS). In this paper, the three parts of the methodology – the heritage significance evaluation, the heritage impact definitions and the heritage balancing process – are discussed and their use illustrated by two example case studies.

Keywords: assessment methodology, building conservation, building renovation, energy-related retrofit, heritage significance, historic buildings, historic cities, urban conservation

1. INTRODUCTION

The project Energy Efficiency for EU Historic Urban Districts' Sustainability (EFFESUS) [1], which has received funding from the European Union (EU) through its Seventh Framework Programme for research, technological development and demonstration (FP7), is "researching energy efficiency for European historic urban districts" [2, 3]. EFFESUS is a consortium of 23 partners from 13 European countries and runs from 2012 until 2016. As part of the project, a software tool is being developed to support the decision-making process for the location-specific retrofit of historic buildings and districts. One module of this tool will assess the impacts that energy-related retrofit measures may have on the heritage significance, or cultural significance, of buildings and districts. In this paper, the methodology of this heritage impact assessment is discussed in detail and placed into context within the EFFESUS project and its practical applications.

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The drivers behind the project depend on climate and energy policies of the EU, particularly the '20–20–20 targets' which aim at achieving three key objectives by 2020 [4,5,6,7]:

- a reduction in greenhouse gas emissions of at least 20 per cent from 1990 levels;
- an increase in energy generation from renewable sources to at least 20 per cent; and
- improvements in energy efficiency of at least 20 per cent.

The long-term aim is to reduce greenhouse gas emissions by 60–80 per cent by 2050 [8].

A significant portion of greenhouse gas emissions is associated with the use of buildings. Households alone consumed 27 per cent of Europe's final energy in 2009 [9]. Carbon dioxide (CO_2) "is the most important greenhouse gas from housing and the one most closely related to energy use in homes" [10]. To achieve the set policy targets, significant performance improvements from the European building stock are required, the magnitude of which has been discussed, for example, in a UK residential context [11, 12]. In the UK, 30 per cent of final energy in 2012 was consumed by the housing sector alone [13].

EFFESUS has adopted an inclusive definition of *historic urban district*: "a significant grouping of old buildings, built before 1945 and representative of the period of their construction or history" and comprising "buildings which are not necessarily protected by heritage legislation" [14]. Whereas the quantum of Europe's historic building stock which has officially been designated as heritage amounts to less than 3 per cent of the total, the extent of the pre-1945 stock is more than 23 per cent [15], much of which will possess heritage significance and contribute to cultural identity and placemaking. Additionally, it has been estimated that 80 per cent of the European building stock that will exist in the year 2050 has already been built (for Scotland, the estimate for residential properties is, at 87 per cent, even higher), posing both a challenge as well as a major opportunity to demonstrate that the retention of the historic building stock has a significant role to play in mitigating climate change impacts, by reducing the embodied energy associated with its replacement.

The majority of historic buildings are located in an urban environment, with building groups often giving districts their own, distinct character. These historic buildings and districts are material expressions which have significance to present and future generations and form part of our tangible cultural heritage. This significance can be defined as "a combination of all the values assigned to an object". Such a value is an "aspect of importance that individuals and a society assign(s) to an object … Values can be of different types, for example: artistic, symbolic, historical, social, economic, scientific, technological, etc." [16].

Historic buildings and districts are generally perceived to be less energy efficient than those built during the last two to three decades. The European Directive on the Energy Performance of Buildings sets improvement targets for the retrofit of Europe's building stock, but allows for the exemption of the statutorily designated heritage [17]. While this exemption is important, only if the totality of the historic building stock is considered can the set European policy targets be met when discussing energy performance improvements. In addition, of key importance in the decision within the EFFESUS project to adopt the larger statistical measure are the economies of scale that arise from mainstreaming retrofit technologies whose application otherwise would be too specialised and costly.

The assessment methodology discussed in this paper consists of three parts:

- heritage significance evaluation: a system to assess the heritage significance of buildings and districts in sufficient detail to allow making informed decisions about retrofit measures;
- heritage impact definitions: repositories of retrofit measures defining their impacts on heritage significance; and
- heritage balancing process: a process to balance heritage significance with the heritage impacts of retrofit measures.

In the following, the methodology is firstly placed into context of the EFFESUS project, then discussed in detail and finally illustrated with two example case studies.

2. EFFESUS RESEARCH PROJECT

2.1. Project objectives

The EFFESUS project is directed at improving, on a district scale, the energy performance of historic buildings and reducing associated CO_2 emissions. For this, the project considers three types of retrofit measures:

- improvements in the thermal performance of the building fabric and technical building services;
- improvements in the energy management of buildings; and
- decarbonisation of the energy supply through energy generation from renewable sources, be they retrofitted to individual or groups of buildings, or installed as neighbourhood or district systems.

The project has three objectives. First, to develop a variety of retrofit solutions – some new and some adapted from existing technologies for use specifically in a heritage context. Second, to develop, as a tool, a methodology to support the decision-making process for retrofitting historic buildings on a district scale. And, third, to provide outreach and training activities to disseminate its research outcomes. These three project objectives are supported by seven case studies, located in historic districts in the cities of Benediktbeuern near Munich (Germany), Budapest (Hungary), Genoa (Italy), Glasgow (UK), Istanbul (Turkey), Santiago de Compostela (Spain), and Visby (Sweden). This paper focuses on the heritage impact assessment, one of six modules of the decision support system.

2.2. Decision support system

The EFFESUS decision support system is a software tool to aid those making decisions about retrofitting historic districts on the practical and strategic levels. It is anticipated that the tool, predominantly, will be used by professionals, ranging from architects to urban planners, from developers to energy managers, and from local to national policy makers. The software tool assesses the impacts of a large variety of retrofit measures in order to provide a priority list of those packages of measures most suitable for a specific historic district. The tool uses as inputs two sets of data collections: one set is a spatial data model; the other consists of technical repositories.

The spatial data model provides location-specific information about the building stock, its energy use, associated CO_2 emissions and heritage significance, together with data on local climatic conditions and climate change predictions. The software tool uses this data to conduct location-specific assessments, meaning that results for a Mediterranean location will differ from those for a Nordic location, for example.

The second data collection set comprises repositories, or libraries, of retrofit measures. These repositories contain all technical details required by the software tool for each measure. For EFFESUS, two such repositories have been developed. One repository contains measures to retrofit building fabric and technical building services, including systems to manage energy use in buildings. The other repository lists measures to decarbonise the energy supply through energy generation from renewable sources. These technical repositories are generic, and their data are not location-specific.

The decision support system uses these two datasets as inputs in order to model the impacts of each retrofit measure listed in the repositories for a specific district. The system's output comprises a priority list of packages of measures most suited for the retrofit of the district modelled. The tool itself therefore will not determine the results, and outcomes will not be uniform. The aim is not to predetermine what is the preferred or 'best' retrofit solution for a particular situation, but rather to ensure transparency of the process and equivalence within parallel operational contexts. It should be noted that, although the EFFESUS project and its software tool focus on Europe, replacing certain data in the two collections with data for non-European locations allows the software tool to be usable in other world regions.

2.3. Impact assessment modules

The software tool assesses the impact of each retrofit measure on the energy performance of a building in use, i.e. its operational energy consumption and associated CO_2 emissions. However, this is only one of six assessment aspects identified for use with the tool. In addition to the impact assessment for operational energy, the software tool also assesses the impacts of each measure on indoor environment, fabric compatibility, heritage significance, embodied energy, and economy. The impact assessment of the indoor environment covers, for example, changes to indoor air quality and humidity levels. The assessment of fabric compatibility considers chemical or physical reactions occurring because of a retrofit, for example, due to increased moisture levels within the building fabric potentially leading to accelerated deterioration. The assessment of heritage significance evaluates the impacts of retrofit measures on heritage significance. It is this assessment module which is discussed in detail in the next section of this paper. The embodied energy assessment factors the CO_2 emissions associated with the installation (and de-installation) of retrofit measures into the assessment process. This, together with the operational energy assessment, enables the full life cycle of retrofit measures to be covered. The economy assessment establishes the payback periods of retrofit measures and other economic benefits.

It is worth pointing out that the heritage impact assessment evaluates only the impacts on heritage significance and does not consider issues of fabric deterioration due to material incompatibilities, including the concept of reversibility, a fundamental conservation principle. These issues will be assessed by the tool as part of the module fabric compatibility.

Taken together, these six modules provide a holistic assessment of the various aspects which can be interrogated to establish the suitability of a specific retrofit measure in a given situation. Omitting one or several of the six modules results in an unbalanced assessment, which ignores potentially vital assessment aspects. Conducting an impact assessment of, for example, operational energy only will not provide information about the impacts on fabric compatibility or heritage significance. Installing a retrofit measure which improves the energy performance of a building but causes long-term fabric deterioration or significant loss of heritage significance should not be considered a sustainable retrofit. To be suitable for a systematic assessment, e.g. for use in software applications, all six impact assessment modules need to be well structured. The EFFESUS project therefore is developing appropriate assessment methodologies for each module.

3. HERITAGE IMPACT ASSESSMENTS

3.1. Assessment objectives

The EFFESUS software tool uses as its two inputs a spatial data model and technical repositories. The data of the spatial model are location-specific. For an impact assessment of retrofit measures on heritage significance, the model, therefore, needs to contain location-specific data on the heritage significance of the buildings and districts under consideration. These data need to be provided by conservation experts, performing a *heritage significance evaluation*. The acquired data need to be stored in a suitably structured format.

The other datasets used as assessment input are technical repositories. These contain all available technical information about retrofit measures, together with information detailing the potential impacts of each measure on heritage significance. The potential impacts need to be defined. Such *heritage impact definitions* are required for each of the measures listed in the repositories. Again, this information needs to be suitably structured, and the structure needs to relate to that used in the data model to allow evaluation. These data will be provided by EFFESUS as part of its development of the two repositories.

Using both datasets allows a comparison of the heritage significance of the buildings and district against the impacts that retrofit measures will have on them. In other words, the data from the heritage significance evaluation are compared with the data from the heritage impact definitions. Thereby, the two datasets can be ‘balanced’ with each other. This *heritage balancing process* leads to an output which can be used to support the decision-making process for retrofitting historic buildings and districts. All three items together form the heritage impact assessment. (Fig. 1)

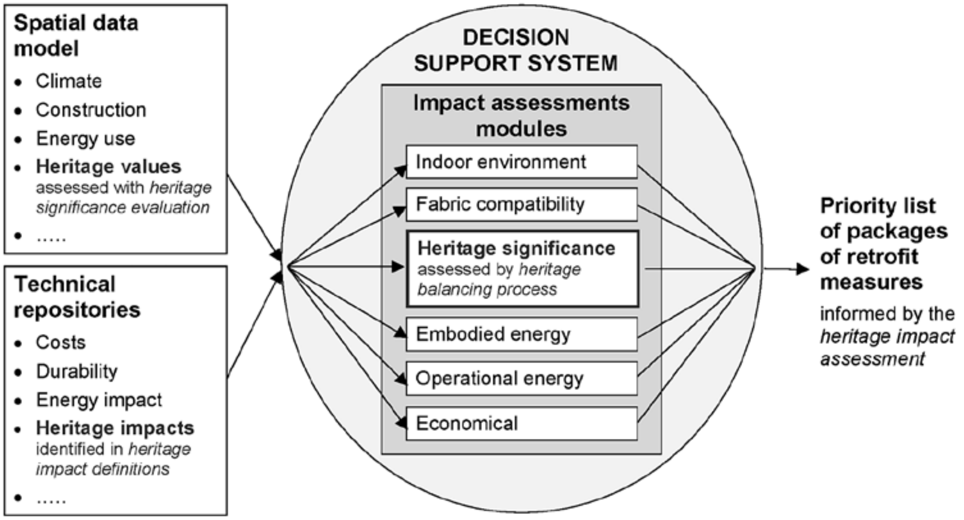

Fig. 1 The EFFESUS decision support system, a software tool, uses two data input sets – a spatial data model and technical repositories – to interrogate, with six assessment modules, the various aspects of impacts of the retrofit measures

3.2. Heritage significance evaluation

The purpose of the heritage significance evaluation is to establish the heritage significance of the subject buildings and district. There is no generally accepted standard detailing how heritage significance should be evaluated, and procedures vary throughout Europe and across the world. The EFFESUS system is being developed in recognition of this and is envisaged as a flexible rather than an absolute tool. Its purpose, through a series of checklist questions, is to lead its users to enquire into the parameters that determine their perception of the heritage significance of individual parts of a district and its buildings, so that informed assessments can be made.

Official heritage designation generally can be used as a basic indicator for heritage significance. On an international level, this can take the form of designation as a World Heritage Site. On a national level, statutory heritage designations for historic buildings include, for example, in the UK: *listing*, *scheduling* and inclusion in a *conservation area*; in Germany: designation as *Baudenkmal* and *Denkmalensemble*; and, in France: designation as *monument du patrimoine*, *zone protégé* and *secteur sauvegardé*.

Prior to officially designating a historic building, an evaluation of its heritage significance is normally carried out and associated documentation is published. Sometimes, the heritage significance is further qualified by assigning heritage grades or categories. In the UK, for example, listed buildings are classed into 'grades' I, II*, or II in England and 'categories' A, B, or C in Scotland. However, statutory heritage significance evaluations tend to be not very detailed and do not generally assign different levels of significance to different parts of a building. In other words, they do not generally identify the character-defining elements of buildings.

Furthermore, heritage-designated buildings constitute only a small portion of the historic building stock, and it is currently rare for a heritage significance evaluation to be conducted for non-designated buildings. To assess the impacts of retrofit measures, a more detailed appraisal of the heritage significance is required to determine which building elements, or building components, can be altered and to what degree. For example, to determine if replacement of existing windows would be acceptable in a specific case requires an understanding of the heritage significance of the existing windows or the contribution that these windows make to the heritage significance of the building or district – which may well not be the same.

Conservation plans or conservation statements can provide a framework for the more-detailed heritage significance appraisal of buildings and districts [18]. These documents can identify and evaluate the significance of different areas, parts or zones of a building. However, although more detailed than statutory evaluations, they also do not generally determine in a systematic way the significance of specific building components, or at least groups of components such as windows (or 'windows of the front elevation', 'windows of the principal floor' etc.). To fill this gap, the heritage significance evaluation developed for EFFESUS uses a systematic and elemental approach. Because the EFFESUS project is concerned with historic districts and not just individual buildings, urban aspects have been included while evaluation of the building fabric has been limited to groups of building components. For example, the significance of the component 'window' is evaluated, but no distinction is made between windows of different elevations, storeys or rooms.

The heritage significance evaluation, therefore, considers: first, a variety of assessment locations, which can be broadly grouped into 'urban district', 'building exterior' and 'building interior': second, for each of these assessment locations, the heritage significance is evaluated for three assessment types: visual, physical and spatial; and third, the evaluation is conducted using a five-step scale to assign heritage significance levels.

3.2.1. Assessment location

The terms *building element* and *building component* are commonly used in the construction industry as categories for doors, floors, roofs, walls, and windows. The EFFESUS assessment system copies this approach by using components as assessment locations. However, because EFFESUS is concerned with a district scale, assessment locations are not only used in a building context, but also transferred to an urban level by introducing assessment locations, such as streetscape, underground (e.g. to assess ground archaeology) and vistas. Tab. 1 lists examples of possible assessment locations, grouped into 'urban district', 'building exterior', and 'building interior'. The list is by no means complete and is only meant to be an illustrative example. For the purpose of describing the assessment system in this paper, only a very limited number of assessment locations will be discussed. These locations are streetscape, as an example from the 'urban district' group, and external wall construction, external wall finish and roof covering as examples from the 'building exterior' group. (No assessment locations from the 'building interior' group will be used.) These example locations are used to illustrate how an assessment of the impacts of retrofitting a wall externally with insulation can be carried out.

Groups	Examples of assessment locations
Urban district	exterior spaces, roofscape, **streetscape**, street finishes, underground, vistas
Building exterior	balconies, exterior doors, **external wall construction, external wall finish**, porches, roof construction, **roof covering**, windows
Building interior	ceiling finish, floor construction, floor finish, interior doors, interior wall construction, interior wall finish

Tab. 1 Examples of assessment locations split into the three groups 'urban district', 'building exterior' and 'building interior', with those locations used in the case study assessments of this paper highlighted in bold

There is a certain overlap with some of the proposed assessment locations, for example, when considering that a streetscape is formed, among other items, by windows and walls, yet it operates on a spatially different scale than the assessment locations external wall construction, external wall finish and windows. Retrofitting a wall externally with conventional insulation will change the spatial configuration of the building envelope, but this could be considered as only of limited spatial impact on the streetscape. Similarly, a distinction is made between a wall's construction and finishes. A timber-framed wall construction might be of outstanding heritage significance, while its rendered wall finish might be only of minor significance, for example, if it has been renewed with non-original materials.

Not all assessment locations are always applicable. Some walls are left exposed without any other material added as finish, thereby making the location external wall finish in this case *not applicable*. The case study examples below illustrate how these different assessment locations can be used in practice.

3.2.2. Assessment types

For each of the assessment locations defined above, an evaluation of their heritage significance is required. Three assessment types were used for this: visual, physical, and spatial. These allow for assessment of the importance of each location in terms of its visual appearance, physical materiality and spatial configuration. Clearly, not every assessment type applies to all assessment locations and, in particular, the type 'spatial' might be of limited use. When discussing the assessment location underground, e.g. with regard to ground archaeology, assessing 'spatial' significance is meaningless. When assessing the significance of wall finishes – externally or internally – 'spatial' could be used to relate to sculptural ornamentation, such as cornices and mouldings, which might be impacted if a thick layer of surface-mounted insulation were to be retrofitted.

3.2.3. Heritage significance levels

With the structure proposed above, heritage significance can be assessed not only as an overall value for a building, but also in far more detail for each assessment location and each assessment type. This means that differentiation now can be made when determining the significance of, for example, walls and windows, and the appraisal also can distinguish if this significance is due to visual appearance, physical materiality or spatial configuration, or a combination of all three.

A heritage significance evaluation simply could state if an assessment location is of significance or not. However, such a binary approach would be a rather crude assessment. To be able to better qualify the level of heritage significance, the use of a five-step scale is proposed for EFFESUS. This allows heritage significance levels (HSL) to be assigned from the range 0–4, with the higher the number, the higher the level of heritage significance. A level of 4 identifies 'exceptionally outstanding significance', HSL 3 describes 'outstanding significance', HSL 2 'major significance', and HSL 1 'minor significance'. Level '0' is used for neutral or negative significance and also where an assessment is not applicable. Tab. 2 lists these heritage significance levels together with illustrative examples and their potential meanings in a practical conservation context.

HSL	Significance	Example for render	
		Illustrating description	Potential results
0	Negative or neutral (or assessment not applicable)	Recently applied cement render in a location which traditionally would have had a lime render	Loss or damage would not be considered problematic and might even be considered beneficial
1	Minor	Traditional render	Loss and damage might be considered acceptable
2	Major	Older traditional render or render with ornate decoration	Loss might be considered acceptable under special circumstances; damage should be minimised
3	Outstanding	Older, rarer, traditional render with or without ornate decoration	Loss is considered unacceptable and damage should be kept to the absolute minimum
4	Exceptionally outstanding	Older, rare traditional render with ornate decoration of outstanding quality, e.g. 16th century pargetting	Any form of damage or loss is considered completely unacceptable

Tab. 2 Heritage significance levels (HSL) ranging from 0 to 4 with illustrative examples

By going further than just declaring, through heritage designation, a historic building or district as being of heritage significance, the proposed EFFESUS appraisal system provides the opportunity to assign qualitative values to a relatively complex set of combinations of assessment locations and types. This system should be able to provide sufficient detail to allow an informed decision-making process when considering where in a historic district the installation of retrofit measures might be acceptable. However, to be able to assess which measures would be acceptable for a specific heritage significance level, the impact that retrofit measures have on heritage significance needs to be defined, using a methodological approach similar to that used for the heritage significance evaluation.

3.3 Heritage impact definitions

The impacts of retrofit measures vary from measure to measure. Therefore, the impact each measure has on the heritage significance of an assessment location and type needs to be defined. The retrofitting of windows with secondary glazing has obviously a different impact than the installation of geothermal heat pumps under an urban square. However, even when looking at retrofitting a specific assessment location, differences exist between different retrofit measures. For example, 'conventional' wall insulation might be 100 mm thick, whereas non-conventional wall insulation systems, such as insulating lime renders, might only have a thickness of 30 mm, and insulating paints can be less than 1 mm. The heritage impacts of these three wall insulation systems will be discussed further in the case studies. Obviously, these measures differ not only in their thickness, but also in their chemical composition, physical performance, life-cycle performance, financial costs etc. However, these factors are not relevant to the heritage impact assessments, as such assessments will be carried out by the other modules of the EFFESUS software.

The heritage impact definitions for retrofit measures are part of the technical repositories, developed by EFFESUS, cataloguing as many measures as is reasonably practical. These definitions are required for each measure and need to be structured in the same form as the data from the heritage significance evaluation to allow comparison and balancing. Therefore, the same structure of assessment locations and types is used.

Definitions are made by assigning an impact level to each combination of assessment location and type. Again, a five-step scale of 0 to 4 is used to quantify the heritage impact levels (HIL). The higher the number, the more severe the impact. Level '0' is used for situations with no negative impact and where the assessment is not applicable to a specific location-type combination. Examples of how heritage impact levels can be assigned to different systems of external wall insulation and photovoltaic roof panel systems will be discussed in the examples case studies in section 4.

3.4. Heritage balancing process

Above, we have discussed two input datasets: one detailing the heritage significance of historic buildings and districts, the other defining the impacts which the installation of retrofit measures will have on heritage significance. Both datasets are structured in the same way, using the same assessment locations and types. This now allows the systematic comparison of the two datasets. In an iterative process, the heritage impact levels of each catalogued retrofit measure can be compared to the heritage significance levels for every combination of assessment location and type. The installation of some measures will have a more severe impact on heritage significance than others; and higher levels of heritage significance will be assigned to some assessment locations and types compared to others. While a measure with a severe impact might be unacceptable, from a conservation perspective, for use with components with a high level of heritage significance, the same measure might well be acceptable for components of minor significance, and definitely would be acceptable where the heritage significance is neutral or negative. This means that a process is required to compare and balance the data from the two sets. Tab. 3 outlines how such a heritage balancing process might be carried out.

Comparing the datasets using the proposed heritage balancing process, thereby, can result in a list which prioritises retrofit measures according to their suitability in respect of their heritage impact on the specific building being analysed. The prioritizing of the results is achieved by ranking the installation of retrofit measures, in a specific situation, as *acceptable*, *likely acceptable*, *potentially acceptable,* or *not acceptable*.

The heritage impact assessment, with its heritage significance evaluation, heritage impacts definitions and heritage balancing process, is only one of six modules in the EFFESUS decision support system. The other modules also will produce priority lists of retrofit measures. These lists, in the end, can be combined to establish which measures are most suitable for use in buildings of a specific historic district, factoring in all the impact aspects analysed in the EFFESUS decision support system.

Heritage significance level	**Heritage impact level**	**Balancing result** *Use of retrofit measures is …*
0 neutral or negative significance	0, 1, 2, 3, 4	acceptable
1 minor significance	0 or 1	acceptable
	2 or 3	likely acceptable
	4	potentially acceptable
2 major significance	0	acceptable
	1	likely acceptable
	2 or 3	potentially acceptable
	4	not acceptable
3 outstanding significance	0	acceptable
	1	likely acceptable
	2	potentially acceptable
	3 or 4	not acceptable
4 exceptional outstanding significance	0	likely acceptable
	1	potentially acceptable
	2, 3 or 4	not acceptable

Tab. 3 The heritage balancing process compares heritage significance levels with heritage impact levels.

4. EXAMPLES

4.1. Overview

How does the heritage impact assessment, discussed so far abstractly, work in practice? Two examples will be used in the following to illustrate the system's applicability. The first example is the assessment of three types of external wall insulation systems to be applied to historic houses in Sweden. The other example looks at three photovoltaic panel systems to be installed on the roofs of two historic houses in Britain. For simplicity, the case studies will only adopt some of the assessment locations and types introduced above.

4.2. Exterior wall insulation

4.2.1. Heritage significance evaluation of external walls

The historic centre of Visby, a city on the Swedish island of Gotland, will be used, in 2016, by the EFFESUS project as a case study to demonstrate the applicability of its software tool. It, therefore, seems appropriate to also use Visby in this paper to illustrate the heritage impact assessment system. For this, four neighbouring houses have been chosen, forming one side of a small square. The square lies in an early extension of the medieval city centre, dating from the 18th and 19th centuries. Both the city centre and the extension are part of the World Heritage Site Hanseatic Town of Visby [19]. The buildings have been chosen to reflect a typical rather than an exceptional historic district.

The four selected houses are all single-storey, timber-framed buildings with gambrel or pitched roofs (Fig. 2). The walls are finished with plaster, except one house which is timber-boarded. Windows and doors are made from timber. The roofs are covered with red pantiles and have either roof lights or dormers. In order to carry out an assessment, it is assumed that one building will be chosen as representative of the assessment area. From the photo, the second building from left was selected as the representative building.

Fig. 2 From a group of four buildings, the second building from left was selected as representative building for heritage impact assessment. (Image © Fredrik Berg)

The heritage significance of this building will need to be assessed by a conservation expert, using the proposed structure of assessment locations, types and levels. How such a heritage significance evaluation could look like is shown in Tab. 4, but only for three select assessment locations: streetscape, external wall construction and external wall finish.

Assessment location	Assessment type	HSL	Significance	Comments / Explanations
Streetscape	physical	0	*not applicable*	not applicable to this location-type combination
	spatial	0	*neutral*	no spatial elements, e.g. porches
	visual	3	*outstanding*	appearance of facades typical for construction period and contributing to identity of place
External Wall Construction	physical	3	*outstanding*	original 18th century framed construction
	spatial	0	*not applicable*	not applicable to this location-type combination
	visual	0	*not applicable*	not visible
External Wall Finish	physical	1	*minor*	often no longer original finishes
	spatial	2	*major*	widely projecting cornices; retaining the original line of wall finishes is considered important
	visual	3	*outstanding major*	appearance typical for construction period

Tab. 4 Example of a heritage significance evaluation, defining heritage significance levels (HSL) for a select number of assessment locations and types, for a historic building in Visby representing a small building group

The evaluation concludes that the visual appearance of the streetscape in general is of *outstanding* significance (HSL 3). That means that the overall appearance should not be prejudiced by retrofits. (For streetscapes, the spatial impact is not applicable.) The external wall construction is considered of physically *outstanding* significance, but is not visible from the outside, hence the spatial and visual significance levels of both are 0. The significance of the external wall finish, by contrast, is considered to be visually outstanding (HSL 3); spatially, they are of *major* significance (HSL 2), but only of *minor* significance physically (HSL 1), as the renders are no longer original. So, a replacement of the renders should be acceptable, as long as the new render has a very similar appearance and is of a similar thickness.

4.2.2. Heritage impact definitions of three external wall insulation systems

Three systems of external wall insulation will be considered for this illustrative examples. Insulation A shall be 100 mm conventional insulation, finished with 10 mm render. Insulation B shall be insulating lime render of 30 mm thickness. Insulation C is an insulating paint coating. The latter will be applied on top of the existing render, the other two insulation systems (A & B) will replace the existing render. The technical repositories will include data for these three generic insulation systems. This data will include heritage impact definitions, detailing the impact an installation of these retrofit measures would have on heritage significance. How the repository data might look like for the three insulation systems is shown in Tab. 5, again using only the assessment location streetscape, external wall construction and external wall finish.

Assessment location	**Assessment type**	**Heritage impact levels (HIL) of three wall retrofit measures (with comments)**		
		Insulation A 100 mm conventional insulation, rendered	Insulation B 30 mm insulating lime render	Insulation C Insulating paint coating applied to existing render
Streetscape	physical	0 not applicable	0 not applicable	0 not applicable
	spatial	2 some increased thickness (in urban context)	0 no change in thickness (as thick as existing)	0 no change in thickness (existing render retained)
	visual	1 influences appearance	0 no change in appearance	1 minor appearance change
External Wall Construction	physical	1 mechanical fixings	0 no physical impact	0 no physical impact
	spatial	0 not applicable	0 not applicable	0 not applicable
	visual	4 alters appearance of exposed construction	4 alters appearance of exposed construction	4 alters appearance of exposed construction
External Wall Finish	physical	4 replaces existing render	4 replaces existing render	0 applied to existing render
	spatial	4 substantial increase in thickness	0 no change in thickness	0 no change in thickness
	visual	1 alters appearance slightly (modern render)	0 no change in appearance	1 alters appearance slightly (even if opaque coating)

Tab. 5 Example of a heritage significance evaluation, using a select number of assessment locations and types, for a historic building in Visby representing a small building group

The conventional insulation has a large physical and spatial impact (HIL 4) on the external wall finish (replacing the existing render) and also a small impact on the streetscape (HIL 1). The impact on the external wall construction is 4 visually (a rendered wall is not the same an exposed wall construction), 1 visually (minor damage due to mechanical fixing), and 0 spatially. The insulating lime render is visually similar to the existing render, hence its impact levels are 0 visually for all three assessment locations, 0 physically for streetscape and external wall construction (no mechanical fixings) but 4 for the external wall finish (replacing the existing render). As the replacement render is approximately as thick as the existing, the spatial impact level is 0.

4.2.3. Balancing heritage significance of an external wall with the impacts of external wall insulation

The heritage significance levels and heritage impact levels can now be balanced against each other, using the heritage balancing process set out in Tab. 3. The assessment results are listed in Tab. 6. For the discussion here, look at the external wall finish, starting with the physical assessment type. Because the existing render is neither original nor an exact like-for-like replacement, the physical significance level of the external wall finish is assumed as *minor* (HSL 1), which means that replacement might generally be an option. This means that, in this specific situation and in accordance with the proposed heritage balancing process, even the conventional insulation and the insulation limes render (Insulation A and B respectively in the table) are considered as *potentially acceptable* retrofit measures, despite their high impact levels (both HIL 4). The insulating paint (Insulation C with HIL 0) is obviously *acceptable*. Spatially, the external wall finish has a significance level of 2, which means that replacement finishes could slightly differ in thickness or proportion. The conventional insulation, with its spatial impact level of 4, would be *not acceptable* though. Because the lime render replacement has a similar thickness to the original render (HIL 0), it would be an *acceptable* retrofit measures, as would the insulating paint, having the same impact level. Lastly, because the render has been given a visual significance level of 3 (*outstanding*), its appearance must generally be retained, with only minor deviations acceptable. The three insulation types discussed have visual impact levels of 0 or 1 and, therefore, are either *acceptable* or *likely acceptable* as retrofit measures. This means that, overall, for the assessment location external wall finish, the conventional insulation is *not acceptable* as retrofit, because of its spatial impact; the insulating lime render is *potentially acceptable*, despite replacing existing fabric; and the insulating paints is fully *acceptable – physically, spatially and visually*. (It is worth noting once again that this is a heritage significance assessment only. Issues of technical compatibility, including reversibility, are assessed by the fabric compatibility module in the EFFESUS software tool. If insulating paint is given here a fully 'acceptable' from a heritage significance perspective, this does not mean that it is technically appropriate, achieves meaningful energy savings or is economically feasible.)

Location/ Retrofit	physical	spatial	visual	overall
Streetscape	HSL 0 *not applicable*	HSL 0 *neutral*	HSL 3 *outstanding*	
Insulation A	HIL 0 ⇨ *acceptable*	HIL 2 ⇨ *acceptable*	HIL 1 ⇨ *likely accept.*	*likely accept.*
Insulation B	HIL 0 ⇨ *acceptable*	HIL 0 ⇨ *acceptable*	HIL 0 ⇨ *acceptable*	*acceptable*
Insulation C	HIL 0 ⇨ *acceptable*	HIL 0 ⇨ *acceptable*	HIL 1 ⇨ *likely accept.*	***likely accept.***
Wall Constr.	HSL 3 *outstanding*	HSL 0 not *applicable*	HSL 0 *not applicable*	
Insulation A	HIL 1 ⇨ *likely accept.*	HIL 0 ⇨ *acceptable*	HIL 4 ⇨ *acceptable*	*likely accept.*
Insulation B	HIL 0 ⇨ *acceptable*	HIL 0 ⇨ *acceptable*	HIL 4 ⇨ *acceptable*	*acceptable*
Insulation C	HIL 0 ⇨ *acceptable*	HIL 0 ⇨ *acceptable*	HIL 4 ⇨ *acceptable*	*acceptable*
Wall Finish	HSL 1 minor	HSL 2 major	HSL 3 outstanding	
Insulation A	HIL 4 ⇨ potent. accept.	HIL 4 ⇨ not acceptable	HIL 1 ⇨ likely accept.	***not acceptable***
Insulation B	HIL 4 ⇨ potent. accept.	HIL 0 ⇨ acceptable	HIL 0 ⇨ acceptable	***potent. accept.***
Insulation C	HIL 0 ⇨ acceptable	HIL 0 ⇨ acceptable	HIL 1 ⇨ likely accept.	***likely accept.***

Tab. 6 Heritage impact assessment of three external wall insulation technologies for use on the rendered walls of the representative building selected above: The assessment is based on the heritage balancing process set out in Tab. 3. The overall assessment results, marked in bold, are: Conventional insulation (Insulation A) is not acceptable; insulating lime render (B) is potentially acceptable; and insulating paint (C) is acceptable.

4.3 Photovoltaic roof panels

4.3.1. Heritage significance evaluation of two slated roofs

As a second example, the heritage impact assessment will be used to evaluate the impacts of three systems of photovoltaic roof panels. For the assessment, two British buildings with slated roofs were chosen. (Fig. 3) The building on the left side of the figure has its original, 18th century roof covering, which is visible from common viewpoints. The assessing conservation expert could class the roof finish, therefore, as being of heritage significance level 3 physically, spatially and visually. However, let us assume that the slating has reached the end of its life and will need replacing soon. The assessor, therefore, decides that the physical significance merits only a level of 1, *minor significance*.

By contrast, the roof on the right side of the figure is covered in replacement slates, which, hidden behind a parapet, are not easily visible. An assessor might decide that all three assessment types should be set to level 1. However, the replacement covering is a close like-for-like match to the original, worthy of retention. So, the assessor sets the physical level to 3, *outstanding significance*. If the roof covering would have been visible from a footpath on a nearby hill, the visual level might have been 2 or 3.

Fig. 3 The roof in the foreground of the left photograph has its original 18th century slates, visible from common viewpoints, whereas the roof covering on the right photo is a replacement, hidden behind a parapet.

4.3.2. Heritage impact definitions of three photovoltaic panel systems

Three photovoltaic panel systems will be assessed in this case study. Again, generic information about these panel systems will be included in the EFFESUS Technical Repositories. The first system uses raised panels, installed on top of the roof covering. The second is in-line panels, replacing the covering, in order to maintain the original roofline. And the third is ‘solar slates’, mini-panels mimicking the appearance of slates. (Fig. 4) The raised panels could be classed spatially and visually as level 4. But they would only have a physical level of 1, as the existing roof covering is mostly retained, bar a few fixings. The physical level of in-line panels would be 4, as this retrofit measure requires the replacement of the existing slates. The spatial level could be 0, as it does not change the roofline. The visual level might be 4. For the solar slates, the following levels could be assigned: physical 4, as they replace the existing covering; spatial 0, as they do not change the roofline and are flexible with regard to detailing; and visual 1, as they mimic the appearance of the original slates.

Fig. 4 Three photovoltaic panel systems with different heritage significance impact: The left photograph shows raised panels mounted on top of the roof covering, the mid-photo is of in-line panels and the right has solar slates.

4.3.3. Balancing heritage significance of two roofs with the impacts of photovoltaic panels

The heritage significance evaluations of the two roofs discussed and the heritage impact definitions of the three solar panel systems can now be compared with each other to achieve a balanced assessment (Tab. 7). The comparison of significance and impact levels is based on the already discussed heritage balancing process (Tab. 3). For the highly visible roof with original covering (Roof 1 in the table), the use of raised or in-line panels would be *not acceptable* for visual reasons (HSL 3 versus HIL 4). The raised panel would also be *not acceptable* spatially (HIL 4). The solar slates have no spatial impact and only minimal impact visually (HIL 0 and 1 respectively), making them *acceptable* spatially and *likely acceptable* visually. The physical heritage significance level of the solar slates, however, is 4, as they require replacement of the existing covering. But that does not matter much in this situation, as the conservation experts performing the heritage significance evaluation had decided that the slating needed replacing and that, therefore, the physical level should only be 1. Together, HSL 1 and HIL 4 still result in a *potentially acceptable* for the solar slates.

For the hidden roof with replacement covering (Roof 2), all panel systems are with regard to their spatial and visual impacts either *acceptable*, *likely acceptable* or *potentially acceptable*. This is simply because the roof is hidden from view. Because the heritage significance assessor had decided that the replacement roof covering was of physically *outstanding significance* (HSL 3), in-line panels and solar slates become *not acceptable*, as they require the replacement of the slating (HIL 4). The raised panel, however, is physically *likely acceptable*, as the existing slating can be retained (HIL 1). Thereby, the solar slate system achieves a *potentially acceptable*.

Roof/panel	physical	spatial	visual	overall
Roof 1	HSL 1 *minor*	HSL 3 *outstanding*	HSL 3 *outstanding*	
Raised panel	HIL 1 ⇨ *acceptable*	HIL 4 ⇨ *not acceptable*	HIL 4 ⇨ *not acceptable*	*not acceptable*
In-line panel	HIL 4 ⇨ *potent. accept.*	HIL 0 ⇨ *acceptable*	HIL 4 ⇨ *not acceptable*	*not acceptable*
Solar slate	HIL 4 ⇨ *potent. accept.*	HIL 0 ⇨ *acceptable*	HIL 1 ⇨ *likely accept.*	*potent. accept.*
Roof 2	HSL 3 *outstanding*	HSL 1 *minor*	HSL 1 *minor*	
Raised panel	HIL 1 ⇨ *likely accept.*	HIL 3 ⇨ *likely accept.*	HIL 4 ⇨ *potent. accept.*	*potent. accept.*
In-line panel	HIL 4 ⇨ *not acceptable*	HIL 0 ⇨ *acceptable*	HIL 4 ⇨ *potent. accept.*	*not acceptable*
Solar slate	HIL 4 ⇨ *not acceptable*	HIL 0 ⇨ *acceptable*	HIL 1 ⇨ *acceptable*	*not acceptable*

Tab. 7 Heritage impact assessment of three photovoltaic panel systems on two different roofs: The assessment is based on the heritage balancing process set out in Tab. 3.

In the Visby case study discussed in section 4.2, an additional feature has been the installation of a district heating system throughout the World Heritage Site (Fig. 5). The system is served by wood chip burning plants situated outside the historic district which are supplied by managed forestry on the island of Gotland, distributed through a network of hot water pipes laid under the streets, and connected to most buildings in the town.

This urban-scale renewable energy system obviates the need for solar panel installations on individual roofs, as discussed above, thus avoiding any discussion of their impact and protecting the overall integrity of the street and higher level views across and within the district. However, the impacts of the district heating system would need to be assessed instead. The heating system does not impact on the roofs, but heritage impact assessments will be needed, at least, for the assessment locations underground, e.g. regard ground archaeology, and street finishes e.g. historic street surfaces.

Fig. 5 District heating installed below the streets of the city centre of Visby, a World Heritage Site

5. CONCLUSIONS

In this paper, a methodology for heritage impact assessments has been presented. It is one of six modules of the EFFESUS decision support system and is strictly concerned with heritage significance. Other aspects of assessing retrofit measures, such as economic, technical, or energy-related assessments, will be carried out by other modules of the software tool.

The heritage impact assessment allows for the balancing of heritage significance levels, assigned to historic buildings in specific districts, against defined heritage impact levels of retrofit measures catalogued in the EFFESUS technical repositories. The assessment system compares two datasets –heritage significance evaluation and heritage impact definitions – using a heritage balancing process. The heritage impact assessment uses a structured approach with assessment locations (grouped into 'urban district', 'building exterior', and 'building interior') and three assessment types – visual, physical, and spatial.

How the methodology could work in practice has been illustrated in this paper with two example case studies, with a limited number of assessment locations and types and, as example retrofit measures, three different systems of external wall insulation in one case study, and three photovoltaic roof panels systems in the other.

The EFFESUS research project is running until 2016, and the methodology for heritage impact assessments is one of its first deliverables. The methodology presented here requires further development and field-testing. However, the authors hope that presenting it at the development stage to a wider professional audience will foster discussion and encourage feedback, which could help to inform both the future development of the methodology and that of the EFFESUS software generally. Although developed for the EFFESUS software, the heritage impact assessment method is presented here as a conceptual model which could also be integrated into other software packages, e.g. into building information modelling. This could help to embed the assessment of heritage significance into the mainstream retrofit process [21, 22, 23, 24].

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