INTERNATIONAL EXPERT COMMITTEE

REPORT

RISK ASSESSMENT MOVING OF HISTORICAL VIKING SHIPS FROM BYGDØY

FOR

NORWEGIAN MINISTRY OF EDUCATION AND RESEARCH

REV 1.0

Moving of historical Viking Ships from Bygdøy	
For: Norwegian Ministry of Education and Research Kunnskapsdepartementet Postboks 8119 Dep 0032 OSLO Norway	
Account Ref.: Erling W. Wist	
Date of Current Issue: 2012-03-30	
Summary: This document summarizes the evaluation process and the recommendations from the international Expert Committee regarding the possible relocation of the Viking Ships and Fragile Objects at Bygdøy.	
Expert Committee members	
Jesper Stub-Johnsen *Dr and Director of Conservation National Museum of Denmark, Chairman of the Expert Committee*	Signature
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DNV Project No.:	PP010753
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Rev. No.	Date	Reason for Issue	Prepared by
0.9	2012-03-30	First issue verified	Carl Erik Høy-Petersen, DNV on behalf of the Expert Committee

Reference to part of this report which may lead to misinterpretation is not permissible.

The Expert Committee has approved and signed a copy of the report on 25th April 2012.

OPPSUMMERING AV KONKLUSJONER OG ANBEFALINGER

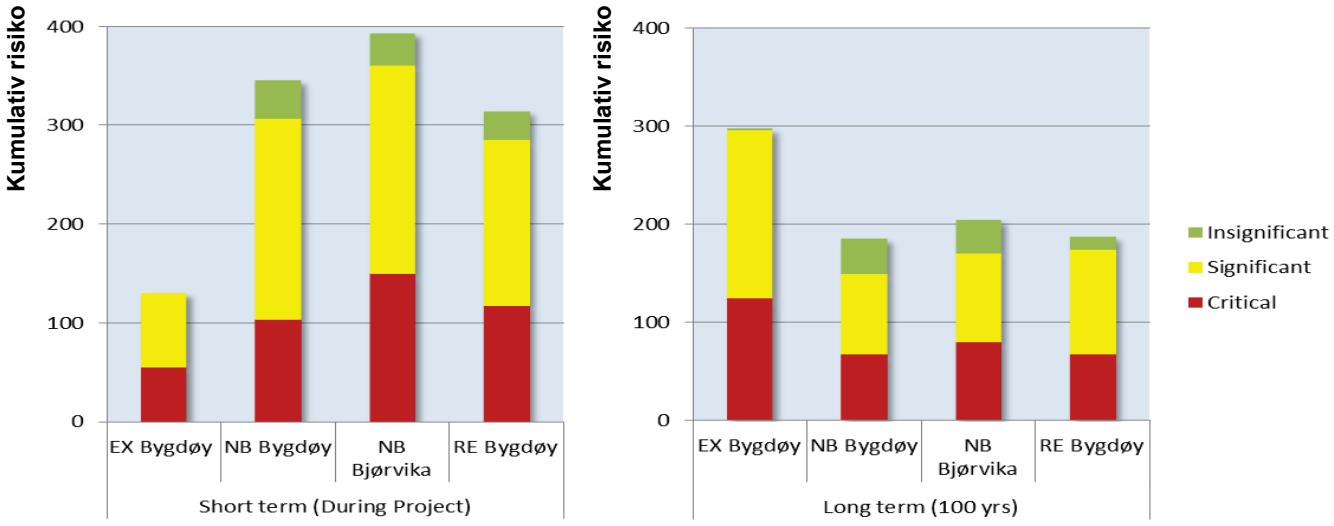
Denne rapporten analyserer og diskuterer risiko relatert til fremtidig bevaring og formidling av Vikingskipene og den tilhørende samlingen ved Vikingskipsmuseet på Bygdøy (Vikingskipsamlingen).

Basert på en evaluering av verdsettelse og ikonisk status på Vikingskipsamlingen i et internasjonalt perspektiv har Ekspertkomitéen konkludert at selv mindre fysisk, kjemisk eller biologisk skade på Vikingskipsamlingen ikke bør aksepteres.

Fire scenarier for fremtidig bevaring av Vikingskipsamlingen er evaluert. Evalueringen har fulgt prinsippene som presenteres under:

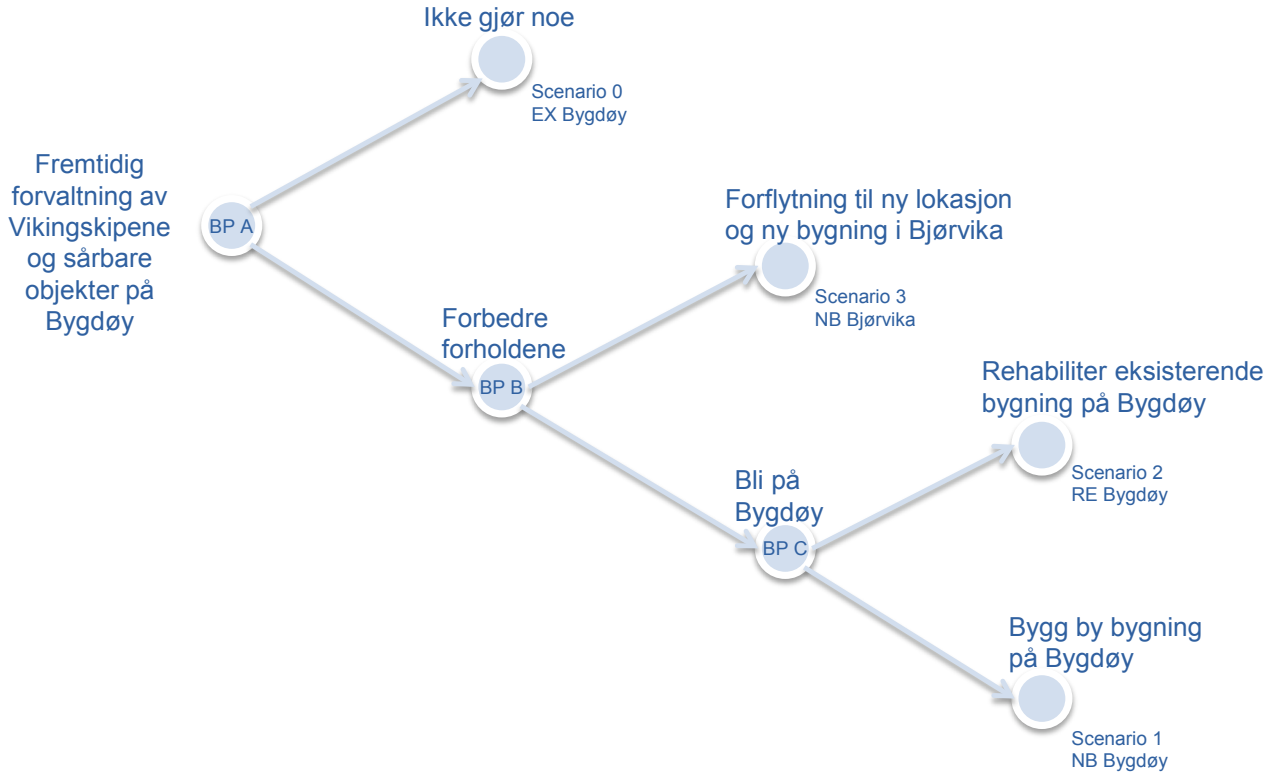
Scenario	Kort beskrivelse	Forkortelse
0	Bli i eksisterende bygning på Bygdøy, ingen tiltak gjennomføres	EX Bygdøy
1	Ny bygning på Bygdøy etterfulgt av en rehabilitering av eksisterende bygning	NB Bygdøy
2	Rehabiliter og bli i eksisterende bygning på Bygdøy	RE Bygdøy
3	Forflytning til ny bygning i Bjørvika	NB Bjørvika

Figuren under oppsummerer resultatene fra risikoanalysen. Stolpene representerer det aggregerte risikobildet for hvert Scenario på kort og lang sikt.



Hvert Scenario innebærer risikoer som vurderes som kritiske. Ingen av Scenarioene som er foreslått for forbedring av forholdene for Vikingskipsamlingen kan gjennomføres uten at det medfører risikoer som Ekspertkomitéen vurderer som kritiske på kort eller lang sikt.

Ekspertkomitéen har vurdert følgende beslutningsproblem knyttet til den videre forvaltningen av Vikingskipsamlingen. Beslutningstreet er benyttet som grunnlag for diskusjonene rundt anbefalinger for den videre forvaltningen av Vikingskipsamlingen.



- Beslutningspunkt A: Ikke gjøre noe eller forbedre forholdene
- Beslutningspunkt B: Bli på Bygdøy eller flytte til Bjørvika
- Beslutningspunkt C: Rehabilitere eksisterende bygning eller bygge ny bygning etterfulgt av rehabilitering av eksisterende bygning på Bygdøy

På bakgrunn av evalueringen har Ekspertkomitéen kommet frem til følgende konklusjoner og anbefalinger:

Konklusjon 1: Vikingskipsamlingen er ansett som unik og høyt verdsatt både i norsk og internasjonalt perspektiv.

Ekspertkomitéen har valgt unikhet og spesielt bevaringsverdig (ikonisk) status som karakteriserende faktorer i evalueringen av akseptabel og uakseptabel risiko.
Komitéen har vurdert Vikingskipene og det som anses som de mest sårbare gjenstandene i den tilhørende samlingen (56 gjenstander). Ekspertkomitéen konkluderer at minst 41 gjenstander i Vikingskipsamlingen er unike og har en spesiell bevaringsverdig status både i et norsk og et internasjonalt perspektiv. Dette bekreftes av internasjonale forskere som Ekspertkomitéen har konsultert. Vurderingen støttes ytterligere av at Oseberg og Gokstad skipene med tilhørende samlinger inngår i nomineringsforslaget til UNESCOS verdensarvliste: *VIKING MONUMENTS AND SITES /Vestfold Ship Burials and Hyllestad Quern stone Quarries, nominated for inscription on the UNESCO List of World Heritage sites*.[1]

[1] which can be found on the UNESCOs World Heritage Sites tentative list http://whc.unesco.org/en/tentativelists/5577/

Av de 41 unike gjenstandene er tilstanden til 15 av gjenstandene vurdert som dårlig eller meget dårlig. Disse kan kun flyttes med vesentlig risiko for skade. Bare tre av gjenstandene er vurdert å være i en god tilstand. Komitéen konkluderer videre at potensialet for ikke-reparerbar skade i utgangspunktet ikke er akseptabelt, men kan være uunngåelig ved behandling av gjenstandene. En eller annen form for behandling av gjenstandene vil være nødvendig i alle Scenarioene på kort eller lang sikt

Anbefaling 1

Komitéen anbefaler at det i forbindelse med et fremtidig prosjekt knyttet til Vikingskipsamlingen gjennomføres nøyaktig dokumentasjon av alle gjenstander og at det tas i bruk beste tilgjengelige analyse- og målingsverktøy, slik som røntgenanalyse og 3D-laser skanning, og at prosessen følger beste praksis innenfor fagfeltet. Dersom endringer skulle oppstå på gjenstandene i fremtiden, vil nøyaktig dokumentasjon legge til rette for reparasjoner og rekonstruksjon.

Konklusjon 2: Hovedtrusselen for Vikingskipsamlingen er direkte fysiske krefter

Av ni identifiserte hoved-risikoer anses den største trusselen på kort sikt å være direkte fysiske krefter som kan føre til strukturell deformasjon og/eller tap av materiale på Vikingskipene og de alunkonserverte gjenstandene.

Anbefaling 2

Et hovedmoment i forkant av enhver from for flytting, relokalisering eller beskyttelse og sikring av Vikingskipsamlingen er å minimere usikkerhet ved å detaljplanlegge, øve og gjennomføre hvert steg i prosjektet med hensyn på de identifiserte risikoene.

Konklusjon 3: Scenariet nytt museumskompleks på Bygdøy har lavest risiko på lang sikt

Hvert av Scenariene Ekspertkomitéen har vurdert vil innebære risikoer som anses som kritiske. Ingen av Scenariene som er foreslått for å forbedre forholdene for Vikingskipsamlingen kan gjennomføres uten det Komitéen anser som kritiske risikoer på kort eller lang sikt.
Den omfattende risikoanalysen gjennomført av Komitéen viser at bygging av en ny bygning på Bygdøy, etterfulgt av en renovering av eksisterende bygning, vil innebære lavest risiko for Vikingskipsamlingen på lang sikt. Samtidig vil en relokalisering eller flytting av Vikingskipsamlingen innebære høyere risiko på kort sikt enn ikke å gjennomføre noen tiltak. Eventuelle fordeler ved å utsette beslutningen og for å dra nytte av fremtidig kunnskap knyttet til konservering og formidling vil imidlertid reduseres som følge av at Vikingskipsamlingen da vil utsettes for fortsatt nedbrytning og endring.

Anbefaling 3:

Komitéen anbefaler at det bør bygges et nytt museum for formidling av Vikingskipsamlingen på Bygdøy i nærheten av den eksisterende bygningen, etterfulgt av en renovering av eksisterende bygning som en del av etableringen av et nytt museumskompleks.

Konklusjon 4: Et nytt museumskompleks på Bygdøy vil forbedre langsiktig bevaring av Vikingskipsamlingen

Selv om dagens innvendige klima ikke utgjør en høy risiko i form av kjemisk og biologisk nedbrytning, vil en forbedring av miljøet og presentasjonsforholdene gjennom en ny og rehabilitert museumsbygning forbedre den langsiktige bevaringen av Vikingskipsamlingen.

Anbefaling 4:

Ved detaljplanlegging av ny museumsbygning og rehabilitering eller forbedring av eksisterende formidlingsmiljø, må det legges vekt på å etablere optimale forhold for bevaring av gjenstandene. Lokaler som skal inneholde Vikingskipsamlingen bør ikke klimatiseres for menneskers velvære, men må fokusere på langsiktig bevaring av objektene i Vikingskipsamlingen.

Konklusjon 5: Alternative restaureringsarbeider og langsiktige kostnader for vedlikehold og bevaring av Vikingskipsamlingen bør estimeres

Kostnadene knyttet til dokumentering, forberedelser og flytting av Vikingskipene og/eller deler av samlingen, etterfulgt av mulige restaureringsarbeider og tilrettelegging for sikker fremtidig formidling, må legges til tidligere kostnadsestimater. Tidligere erfaringer indikerer at disse kostnadene kan bli opp til 10% av de totale kostnadene ved bygging av et nytt museumskompleks. I tillegg bør langsiktige kostnader knyttet til bevaring og vedlikehold av Vikingskipsamlingen vurderes.

Anbefaling 5

Etter ferdigstillelse av prosjektet må tilstrekkelig ressurser gjøres tilgjengelige for å reparere (enhver) skade som har oppstått på Vikingskipsamlingen, inkludert den nødvendige tid til å gjennomføre restaureringsarbeider og formidlingsarbeid før det åpnes for publikum. Langsiktig ressursbehov og kostnader knyttet til vedlikehold, overvåkning, forebyggende konservering og gjennomføring av restaureringsarbeider på Vikingskipsamlingen må også estimeres.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

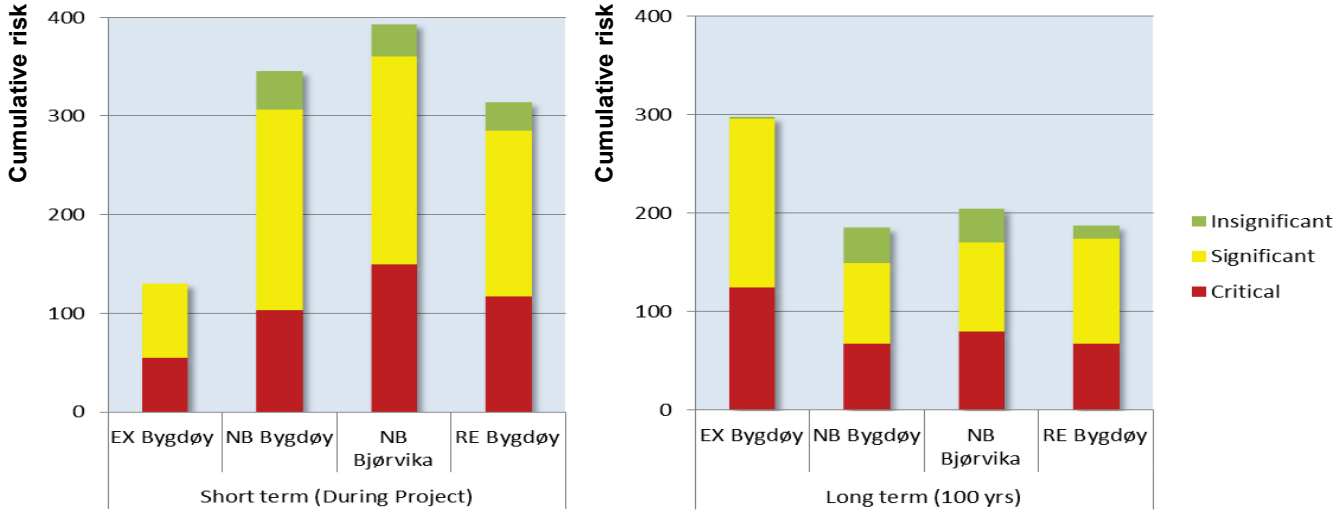
This report analyses and discusses the risks related to the future preservation, dissemination and presentation of the Viking ships and related assemblage present at the Viking Ship Museum at Bygdøy, Norway (Viking Ship Assemblage).

Based on an evaluation of value and iconic status of the Viking Ship Assemblage in an international context the Expert Committee concludes that physical, chemical or biological damage to the Ships and Objects is not acceptable.

Four scenarios for the future presentation of the Viking Ship Assemblage have been evaluated as indicated below:

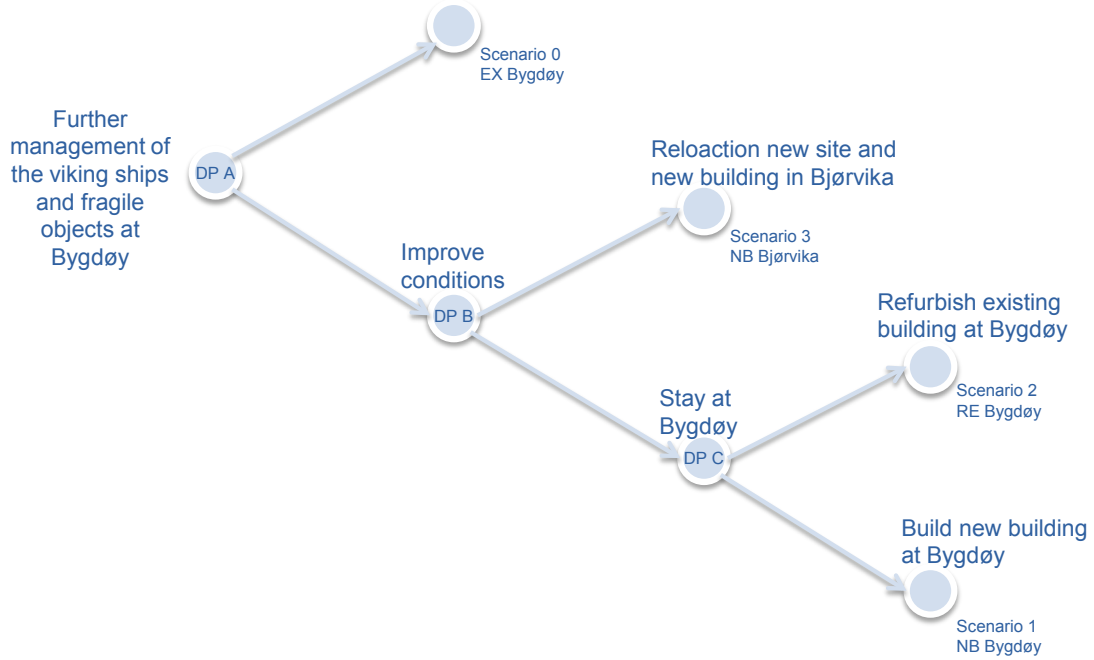
Scenario	Short description	Abbreviation
0	Remain in existing building at Bygdøy, no additional actions are taken	EX Bygdøy
1	New Building at Bygdøy followed by refurbishment of the existing building	NB Bygdøy
2	Refurbish and remain in existing building at Bygdøy	RE Bygdøy
3	Relocation to new building in Bjørvika	NB Bjørvika

The illustration below summarizes the results of the risk assessment process. The columns represent the aggregated risk picture related to each Scenario in short and long term.



Every Scenario has risks that are considered to be critical. None of the Scenarios that are proposed for improvement of the conditions can be completed without what the Expert Committee considers to be critical short or long term risks.

The Expert Committee has considered the following decision problem related to the further management of the Viking Ship Assemblage. The decision tree has been used as a basis for the discussion on recommendations for further management of the Viking Ship Assemblage.



- Decision point A: Do nothing or improve conditions
- Decision point B: Stay at Bygdøy or relocate to Bjørvika
- Decision point C: Refurbish existing building or build new building followed by refurbishment of existing building at Bygdøy

As a result of the evaluation the Expert Committee has come to the following conclusions and recommendations:

Conclusion 1: The Viking Ship Assemblage is recognised as unique and valued both in a Norwegian and international context

In its assessment of acceptable and unacceptable risks, the Expert Committee has chosen uniqueness and iconic status as the characteristic factor.
The Committee assessed the Viking Ships and what is recognised as the most important and fragile parts of the related Assemblage (fifty-six objects). The Committee concludes that at least forty-one objects of the Viking Ship Assemblage are unique and have iconic status both in a Norwegian and international context. This is confirmed by other international researchers consulted by the Committee. This view is further supported by the fact that the Oseberg and Gokstad Ships, and associated Objects, are part of the proposal: VIKING MONUMENTS AND SITES /Vestfold Ship Burials and Hyllestad Quern stone Quarries, nominated for inscription on the UNESCO List of World Heritage sites.[2]
Of the forty-one unique objects, fifteen are in a poor or very poor condition and can only be moved with a severe potential risk of damage. Only three objects are considered to be in a good condition.
The Committee moreover concludes that the potential for unrepairable damage is not acceptable but may be unavoidable when handling the Objects. However some form of handling of the Objects will be necessary in all Scenarios in the short or long term.

[2] which can be found on the UNESCOs World Heritage Sites tentative list http://whc.unesco.org/en/tentativelists/5577/

Recommendation 1

The Committee recommends that as a part of any further projects with the Viking Ship Assemblage, careful documentation of all Objects using state of the art analytical and measurement tools such as X-ray examination and 3D-laser scanning following best practice in the field should be initiated. If any change occurs to the Objects in the future, careful documentation will allow for repair and reconstruction.

Conclusion 2: Top risk is direct physical forces

Of the nine identified top risks, direct physical forces causing structural deformation and or loss of material from the Viking Ships and alum conserved Objects are the major short term hazard.

Recommendation 2

A key aspect before any action on moving, relocating or securing and protecting the Viking Ship Assemblage is to design carefully, rehearse and execute each step in the project taking into account the identified risks in order to minimize uncertainties.

Conclusion 3: Lowest risk Scenario long term is development of a new museum complex at Bygdøy

Every Scenario evaluated by the Committee has risks associated with it that are considered to be critical. None of the Scenarios that are proposed to improve conditions can be completed without what the Committee considers to be critical short term risks or critical long term risks.
Based on the comprehensive risk analysis carried out by the Committee, the construction of a new building at Bygdøy followed by refurbishment of the existing building, has the lowest long term risk for the Viking Ship Assemblage, while relocating or moving the Collection will create a higher risk in the short term compared to doing nothing.
However, by delaying the decision and therefore any action, the conservation and presentation benefits that would accrue at a later stage will be diminished as the Viking Ship Assemblage will have suffered further decay and change.

Recommendation 3:

The Committee therefore recommends that a new museum to display the Viking Ship Assemblage should be built at Bygdøy in the vicinity of the existing building followed by refurbishment of the existing building as part of the development of a new museum complex.

Conclusion 4: A new museum complex at Bygdøy will improve long term preservation of the Viking Ship Assemblage

Although the current indoor climate does not impose a high risk in terms of chemical and biological decay, the improvements to the environment and display conditions that a new and refurbished museum building offer will improve the long term preservation of the Viking Ship Assemblage.

Recommendation 4

When designing the new museum and refurbishing or improving the existing display environment, every effort must be made to create conditions for object preservation and no space housing the Viking ships or assemblage should be climatised for human comfort rather than for the long term preservation of the Objects.

Conclusion 5: Possible restoration works and long term costs for maintenance and care of the collection should be considered

The costs for documenting, preparing and moving the Viking Ships and/or parts of the Assemblage, followed by possible restoration works and preparing new and safe display must be added to the existing estimates of costs. Based on experience, it is estimated that these costs can be up to 10% of the total cost of building a new museum complex. Moreover long term costs for maintenance and care of the Collection should be considered.

Recommendation 5

After project completion, adequate resources must be made available to repair (any) damage that has occurred to the Ships and Objects, including the necessary time for carrying out restoration and display work before opening to the public. The long term resources and costs for maintenance, monitoring, preventive conservation initiatives and carrying out restoration works on the Viking Ship Assemblage must also be estimated.

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1 INTRODUCTION

This report summarizes the findings and evaluations made by the international Expert Committee regarding risks related to a possible move of historical Viking Ships from Bygdøy. The following experts have been invited by the Norwegian Ministry of Education and Research to be part of the Expert Committee:

- Jesper Stub Johnsen, Dr and Director of Conservation, National Museum of Denmark. Chairperson of the committee.
- May Cassar, Professor and Director of the Centre for Historic Buildings, Collections and Sites at University College of London.
- Ronald Bockius, Dr and Head of Research at Romisch-Germanisches Zentralmuseum, Museum forfiir Antike Schiffahrt, Mainz, Germany.
- David Saunders, Dr and Keeper, Department of Conservation and Scientific Research, The British Museum, London.

Det Norske Veritas AS (DNV) has developed the assessment methodology used by the Expert Committee and has facilitated the evaluation in the role of process leader.

1.1 Background

The Viking Ship Museum at Bygdøy in Oslo holds the findings from the Viking burial mounds of the Thune Ship, Gokstad Ship, Oseberg Ship and Borre. The Ships and a selection of the grave furnishings from the finds, mainly from the Oseberg, are on display in the Viking Ship Museum today, in this report this is referred to as the Viking Ship Assemblage.

The first part of the museum building with the Oseberg Ship was ready in 1926. The building has since then been expanded in two stages with the wings for the Gokstad and Thune Ships in 1932 and the last wing with grave finds from the Oseberg Ship burial in 1957.

A number of studies have previously been carried out regarding risks related to possible relocation of the Viking Ships and artefacts. The studies carried out are special reports that deal with particular subjects (e.g. calculations of strength of the Oseberg Ship). The overall picture has been compiled by the University of Oslo. A conceptual evaluation related to possible relocation has been carried out for the location of the Cultural Museum including the Viking Ship Museum. Several alternative locations have been considered. This evaluation has been through a QA1 process - (Quality assurance of large public investments).

The Ministry of Education and Research has found that interfaces and assumptions made in the various reports are not all adequately evaluated by professionals. In addition, the reports lack a scientific assessment of what is acceptable irreversible damage and repairable damage. On the basis of this, international experts have been requested to form an international Expert Committee.

1.2 Mandate of the Expert Committee

The Ministry of Education and Research has formulated the Mandate of the Expert Committee.

The Expert Committee will:

1. Examine, in an international context, what can be accepted as reversible and irreversible damage to the Ships and Objects.

2. Carry out a comprehensive assessment of the risks related to a possible relocation of the Viking Ships and Fragile Objects.
3. If relocation is acceptable, assess and recommend practical implementation of a possible relocation and visualize all the aspects of a removal process.
4. Calculate costs related to moving Ships and Objects, including the repair of damage to the Ships and Objects.

This Mandate has been operationalized by the Expert Committee. This operationalization has been accepted by the Ministry.

Mandate point 1:
Examine, in an international context, what is acceptable physical, chemical and biological change to the Ships and Objects.

Mandate point 2:
Carry out a holistic assessment of the risks associated with relocation of the Viking Ships and Fragile Objects.

Mandate point 3:
Assess and recommend practical implementation of the improvement of the display conditions (safe transport is included). Four Scenarios are to be evaluated as indicated in the table below.

Table 1-1 Scenario overview[3]

Scenario	Short description	Abbreviation
0	Remain in existing building at Bygdøy, no additional actions are taken	EX Bygdøy
1	New Building at Bygdøy followed by refurbishment of the existing building	NB Bygdøy
2	Refurbish and remain in existing building at Bygdøy	RE Bygdøy
3	Relocation to new building in Bjørvika	NB Bjørvika

Mandate point 4:
Calculate the relevant costs related to point 3, including stabilisation and repair.

The Committee's work must be done in an impartial and professional way to assure integrity and acceptance. The Expert Committee members will all represent renowned international institutions. The assignment is to evaluate what information is necessary to carry out the task in accordance with the Mandate.

1.3 From Uniqueness to Value – constraints in the Expert Committee evaluation

As stated in the Mandate, the Expert Committee has evaluated the potential changes that may occur to the Viking Ship Assemblage in each of the Scenarios. In this report the Expert Committee will present a recommendation based on their evaluation of the potential physical, biological or chemical change to the Viking Ship Assemblage in each Scenario.

Based on the recommendation from the Expert Committee the decision maker must take into account how the Scenarios may impact on value aspects both positively and negatively.

[3] For detailed description of each scenario see 3.3.

According to a previous evaluation report, the basis for the evaluation of value is linked to the benefit or utility that can be gained from the Collection. This assumes that there is no value unless there is some involvement of people[4].
Value dimensions defined in a previous study[5] are presented in the table below:

Table 1-2 Value description from previous studies illustrate the relation between the preservation of the Viking Ship Assemblage and its impact in an expanded perspective – see also Figure 1-1.

	Values[5]
A.	The dissemination value of the Collection
B.	The research value of the Collection
C.	The future research potential of the Collection
D.	The management of the Collection
E.	The size of the Collection

Change can have impact in one or more value aspects. The overall aspect of the potential change and impact on value is illustrated in the figure below. The ring structure implies that an impact on the inner ring can have effects in one or several of the dimensions on an outside ring. The impact on values as a result of physical, biological or chemical change to the Objects will to a large degree depend on the uniqueness of the Objects that are affected. Uniqueness of the Objects has, therefore, also been assessed as part of the evaluation and must be taken into account when a final decision is made.

As shown in Figure 1-1, the Expert Committee has focused on the green inner circles from Objects to be assessed, potential physical, biological or chemical change to uniqueness of the Objects. Based on this evaluation and the conclusions from this report the Ministry of Education and research must evaluate value dimensions (blue) - impact on the value of the Assemblage.

[4] Ref: Risk Assessment for Object Conservation – J Ashley-Smith, Butteworth-Heinemann,1999
[5] Ref D-02.01 Risk evaluation of the move of the Collection, Safetec report 2002

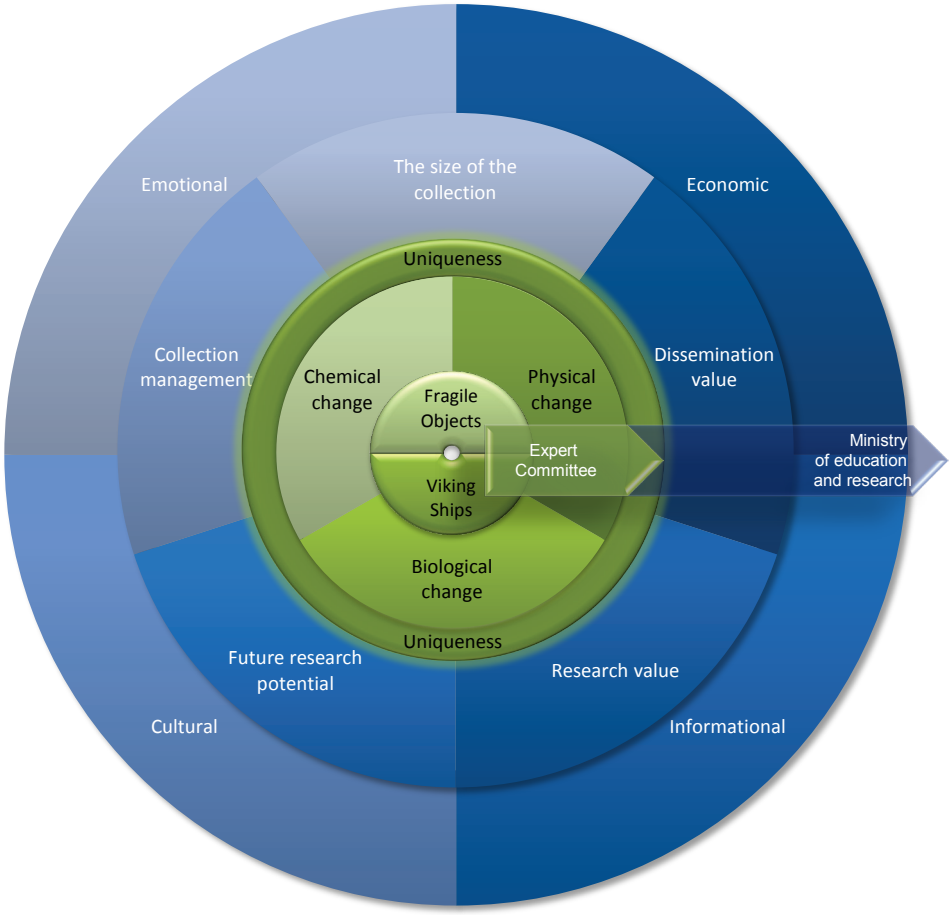


Figure 1-1 Dimensions in the evaluation process, and scope of the Expert Committee's evaluation.

2 OVERVIEW OF THE WORK PROCESS

The work in the Expert Committee has been performed as a combination of document review, meetings and structured workshops. Between meetings and workshops the members of the Expert Committee have reviewed previous reports and evaluated risks and temporary conclusions.
Before each workshop the decision basis has been compiled and structured by DNV and the Chairman of the Committee and distributed to the Expert Committee for comments and evaluation. This has enabled the group to agree on conclusions on the very complex issues related to the management of the Objects in the Viking Ship Museum. For an overview of meetings please refer to Appendix 2.

2.1 Method description

The evaluation by the Expert Committee has followed the process steps as illustrated in Figure 2-1.

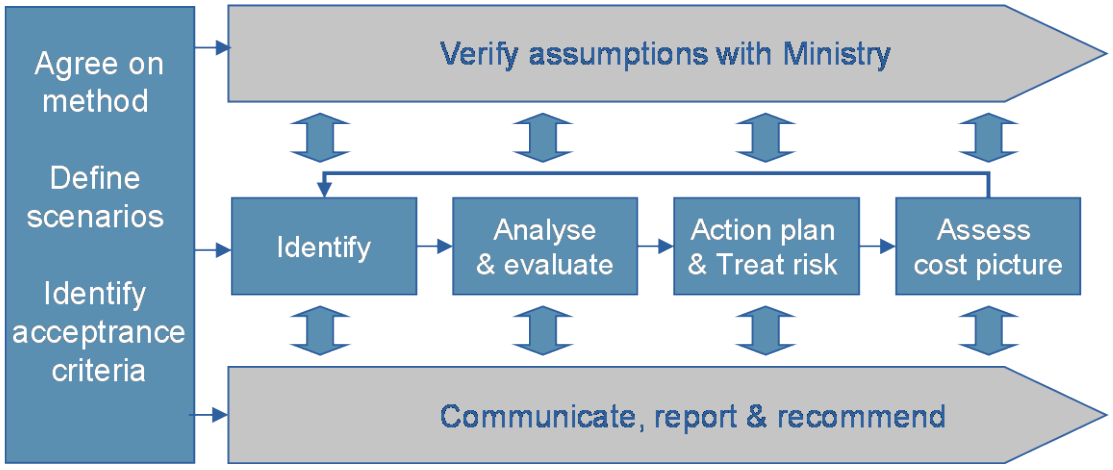


Figure 2-1 Overall evaluation process followed by the Expert Committee

For a detailed step by step description of the evaluation process please refer to Appendix 2.

A breakdown into phases has been used to structure the evaluation process as illustrated in Figure 2-1 below. This breakdown has been used as a reference for discussions related to risks and relevant mitigating actions for the four Scenarios. The breakdown is generic for all Scenarios, and is based on a collective and aggregated evaluation of the phases that are described in previous risk assessments. The risk assessment framework developed by Canadian Conservation Institute (CCI) has been used as a basis for identifying risks and potential mitigating actions related to each phase.

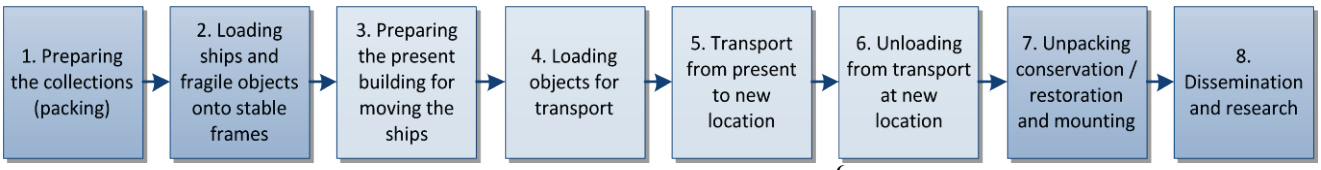


Figure 2-1 Generic breakdown of relevant phases related to the Scenarios[6]

2.2 The assessment is based on the following premises

A new and/or refurbished building will be designed and built according to best conservation and sustainability practice to provide appropriate environments for the long term preservation of the Viking Ship Assemblage.

- All handling, packaging, transportation and unpacking will be done by professionals with competence and experience related to this kind of work supervised by restorers/conservators.
- Conservators from the Viking Ship Museum will be in charge of selection of materials and packing.
- Packing materials used in the process are tested in accordance with best practice and approved

[6] Not all phases are relevant for all scenarios

- If Objects are to be moved out of the building, transport cases used for moving the Objects are designed according to best practice with climate control and adequate 'windows' to allow regular inspection during the process
- All steps in the moving process will be rehearsed with transport cases and simulated weights before the actual Objects are moved
- Objects are not left in crates more than necessary and are not left packed for more than two years under which time they are continuously controlled by conservators.
- All reasonable efforts will be made to repair Objects if damage should occur

The assessment of condition of the Ships and Objects is based on the results from studies made available for the Expert Committee by the Museum and further clarifications from the Museum staff in response to questions from the Expert Committee. See Appendix 1 for a complete list of documents received by the Expert Committee.

In the evaluation of the Scenarios both risks and uncertainty are taken into account. Risks are identified, described and assessed in terms of probability and consequence. However, due to unresolved issues related to the Scenarios there are unknown factors representing uncertainty in addition to the identified risk, e.g. future impact from development of the area in Bjørvika.

2.3 Scenarios to be evaluated

The decision problem related to the further management of the Viking Ships and Fragile Objects can be structured according to Figure 2-2.

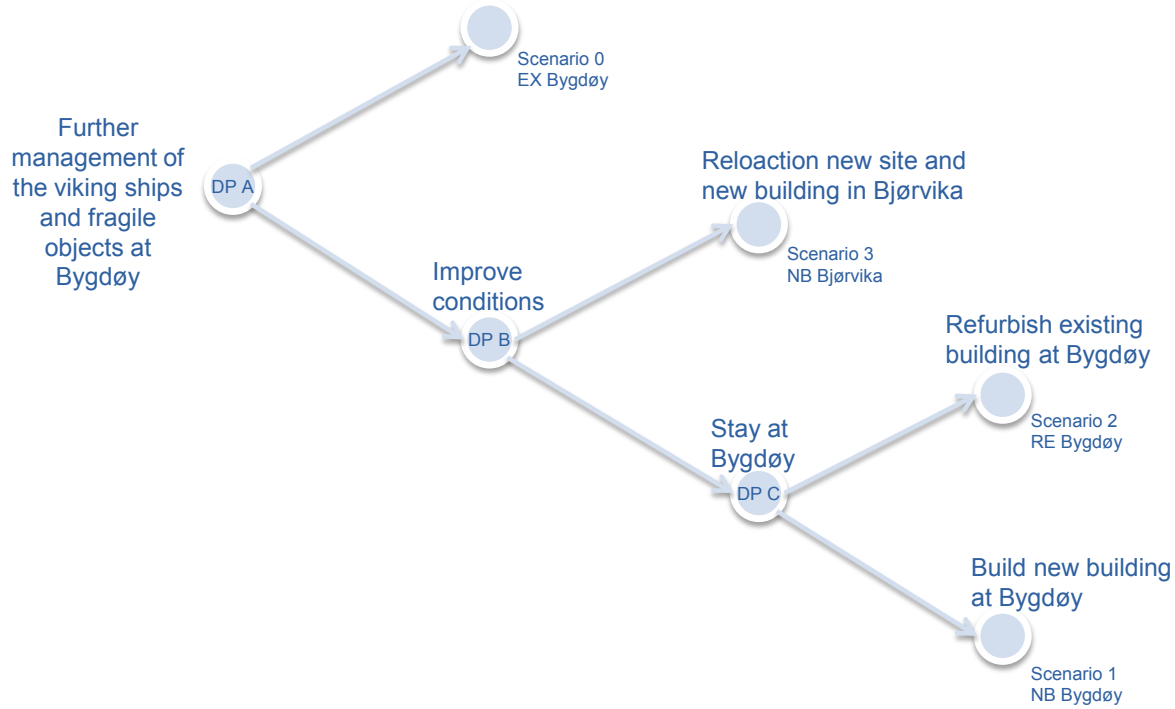


Figure 2-2 Decision breakdown to evaluate Scenarios

The Expert Committee has assessed the risk picture for the four Scenarios:

Scenario	Short description	Abbreviation
0	Remain in existing building at Bygdøy, no additional actions are taken	EX Bygdøy
1	New Building at Bygdøy followed by refurbishment of the existing building	NB Bygdøy
2	Refurbish and remain in existing building at Bygdøy	RE Bygdøy
3	Relocation to new building in Bjørvika	NB Bjørvika

The following sections provide a short description of each of the Scenarios. The description includes assumptions made by the Expert Committee in order to be able to assess the risks for the different Scenarios.

2.3.1 Scenario 0, Remain in existing building at Bygdøy, no additional actions are taken (EX Bygdøy)

Viking Ships and Objects are not moved from the existing building (Figure 2-3). No actions are taken on the building other than routine maintenance.

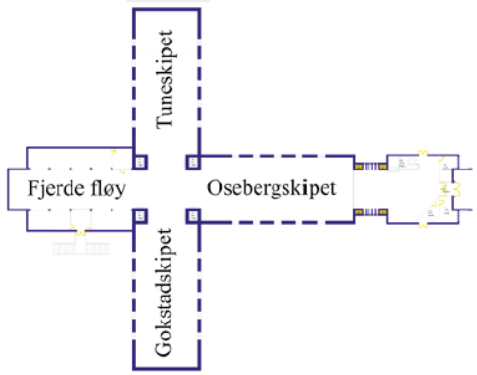


Figure 2-3 Existing building at Bygdøy (D-03.01)

2.3.2 Scenario 1, New building at Bygdøy followed by refurbishment of the existing building (NB Bygdøy)

A new building for the Viking Collection will be constructed at Bygdøy. The actual architecture and location of the new building has not been concluded, as several concepts are proposed, all located in close vicinity to the existing museum building (see example in Figure 2-4). The new building may be connected to the existing building either over or under ground. Ground work will be necessary when constructing the new building. The extent of ground work will depend on the size of the new building.

To allow full freedom to decide when the Objects are moved into the new building, the new building should be designed to allow Objects of all sizes to be removed or moved into the building at any later date.

Protection from impact from construction work is prepared in situ for the Viking Ships and Objects before site preparation and construction starts on the new building (e.g. vibrations, dust, falling objects). After construction, selected parts of the Collection can be relocated to the new museum building. Objects are not moved into the new building until it has been monitored and is deemed to be stable. Objects are allowed time to acclimatize when moved into the new building. The existing

building may need special preparation before items can be moved into the new building (extent of preparation will depend on which items will be moved). Items will be prepared before relocation to the new building e.g. rigid transportation frames with vibration control (which can be done as part of the protection from construction work). Existing building will be refurbished after the new building is completed and stable. To reduce risk exposure during refurbishment, selected Objects may be moved temporarily into the new building while the existing building is refurbished. This process will require a two-phased building project, with a period of stabilization after the new building is completed and start of refurbishment on the existing building. This is likely to impact the cost of the project as mobilisation of building work must take place twice.

Climatisation of both new and refurbished building should create conditions for long term preservation of the Objects rather than for human comfort

Figure 2-4 The Oseberg Museum as it was originally designed by Arnstein Arneberg in 1914 (D-03.01) and an example of new proposed building concept by Riksantikvaren / NAV AS architects.

2.3.3 Scenario 2, Refurbish and remain in existing building at Bygdøy (RE Bygdøy)

The existing building is refurbished according to recommendations by previous studies (see Appendix 1). Climatisation should create conditions for long term preservation of the Objects rather than for human comfort. The improvements could include improved ventilation, air quality, temperature, humidity control, radiation control (sunlight/UV) and improved security (visitor control and visitor flow). Protection from hazards related to construction work is prepared for the Objects before building preparation starts (e.g. vibration, dust, falling objects). Objects in transport category A are protected in situ (see Appendix 3 for an overview of transport categories and classification of Objects). Temporary external storage on site should be considered for Objects where the risk related to moving them is lower than the risk of leaving them in situ (mainly Objects in transport category B to D[7]). Vibration control for the alum preserved Objects is installed before refurbishment. In the long term, after the project, Viking Ships and Objects are displayed in the existing building.

[7] Ref D-106 Viking Ship Collection, Status and Uniqueness evaluation by Jan Bill & Susan Braovac, KHM, UiO

2.3.4 Scenario 3, Relocation to new building in Bjørvika (NB Bjørvika)

A new building for the Viking Ship Assemblage will be constructed within the area in Bjørvika has a planning permission for this purpose. Viking Ship Assemblage will be relocated directly into the new museum building after it is finished, monitored and deemed to be stable.
Climatisation of a new museum building should create conditions for long term preservation of the Objects rather than for human comfort.
The existing building will need to be prepared before selected items can be relocated to the new building. Smaller Objects are moved into the new building before construction work begins on the existing building (e.g. opening up to move the Viking Ships). Items will be properly packed and prepared for relocation to the new building (e.g. rigid transportation frames with vibration control). The transport crates will allow for inspection during the relocation process without opening the crates. Objects within the transport crates will be allowed time to acclimatize to the new building before being unpacked. Protection from hazards related to construction work must be prepared for the Viking Ships and other large Objects before building preparation starts at the existing building (vibration, dust, falling objects).

The north wall of the existing building is dismantled to remove the Oseberg Ship and the east wall will be dismantled for the Gokstad and Thune Ships. Smaller Objects are not unpacked until the large Objects are installed.

Truck/transport container is insulated and climatised. The transport options are by land or by sea. The transport from Bygdøy to Bjørvika will require careful planning to account for all external factors and the time and distance travelled.

The specific location of the building in Bjørvika is not concluded. The location proposed in the concept evaluation was disputed by the Directorate of Cultural Heritage (Riksantikvaren) in 2009 due to the conflict with the current historical setting and potential damage to the valuable cultural heritage in the area. There are significant on-going infrastructure projects in Bjørvika. The proposed track for the “Follobanen” from Oslo Central station to Ski passes under the northern end of the proposed location of the museum.

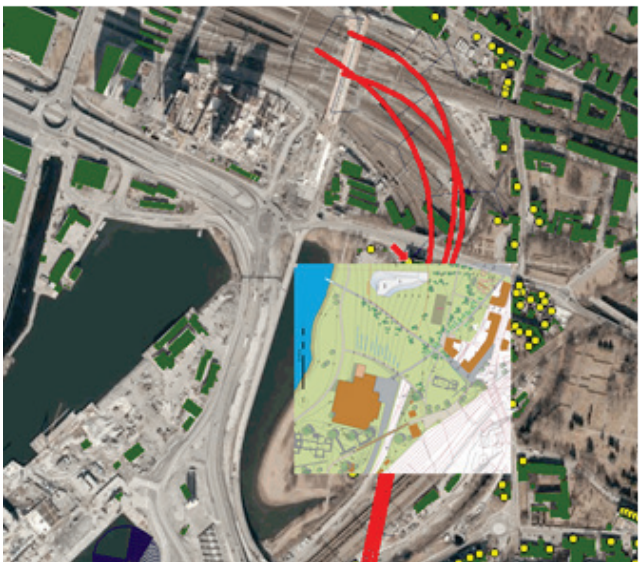


Figure 2-5 Proposed location of new Museum Building and possible conflict with planned rail tunnel with alternative tracks in red on picture to the right (illustration by LPO architects and Jernbaneverket)

3 PROPOSED ACCEPTANCE CRITERIA – WHAT IS ACCEPTABLE CHANGE TO THE SHIPS AND OBJECTS IN AN INTERNATIONAL CONTEXT

The Mandate of the Expert Committee states that the Expert Committee shall:
Examine, in an international context, what can be accepted of reversible and irreversible damage to the Ships and Objects.

This statement has been operationalized by the Expert Committee as:
"Examine, in an international context, what is acceptable physical, chemical and biological change to the Ships and Objects."

The Expert Committee has assessed the potential change in physical, chemical and biological state on the Viking Ship Assemblage. The term damage is exchanged with change as a more open term which includes damage. The evaluation takes into account the potential impact to the unique Objects in the Collection and the overall Viking Ship Assemblage.

3.1 Assessment of protection category and uniqueness of the Viking Ship Assemblage

Appendix 3 gives an overview of the Viking Ships and Objects that are considered as part of the assessment. The list is not complete but is a representative overview of the Objects that may prove complicated to move. In addition to the evaluated objects, the museum also has metal objects and textiles that are not included as they are considered less complicated to move.

The Objects are evaluated in several dimensions:

- Protection category – based on a combination of the following aspects:
  - Condition of the object
  - Type of mount required
  - Number of people needed to carry Object (complexity in moving)
- Uniqueness of the Objects from a Norwegian and international perspective

This protection category and uniqueness evaluation is based on the detailed assessment done in the report 'An evaluation of the Condition of the Viking age Collections at the Viking Ship Museum'[8].

[8] Ref D-02.02 Evaluation of the condition of the Viking Ship Collection, KHM, UiO

Table 3-1 Uniqueness is assessed using the scale below

Uniqueness of the Objects:		Uniqueness description (and mitigation principles when objects are exposed to risk)	Uniqueness in international context (Objects in category)
4	Unique - No known Object of same function/ type/ construction/ shape	Iconic Object – cultural, national, historical, emotional response/value Provides unique research potential (present and future) Part of a historically unique relationship Preventive action is obligatory Need for corrective actions only after thorough expert consultation	41
3	Rare / scarce - Few Objects of same type but no known objects in same state	Not unique but holds symbolic significance Archetype - Opens up understanding about historical associations/ understanding High research potential – one of few objects available to provide knowledge and understanding in specific areas Preventive action is obligatory Minor corrective action acceptable (e.g. replacing rivets)	11
2	Limited / infrequent - Few Objects of same type and some in same state	Exemplar – set point for comparison Considerable research potential – increases the opportunity/ contributes to the knowledge within specific areas Preventive action is a priority, with corrective action if necessary	4
1	Frequent/ extensive - Common, other Objects of same type and state	Research potential adds to building a typology and understanding about use and craftsmanship within specific areas Plays a role within the encyclopaedia of historical information Preventive action is a priority, with corrective action if necessary	0

On request from the Expert Committee, representatives from the Viking Ship Museum have supplemented the original report with an assessment of the uniqueness of the Objects (including the Viking ships) based on a database of findings which contains about 50% of all archaeological finds in Norway. The database shows that there are very few archaeological excavations in Norway with well-preserved wood from the Viking age.

In addition the uniqueness of the Objects has been evaluated in an international context by members of the Expert Committee and by experts from the National Museum in Denmark (NMD). This study supports the evaluation done by the Viking Ship Museum, a few Objects were considered more unique in an international context than the national evaluation. Of the fifty-six Objects evaluated by the NMD senior researchers and specialists in Viking age, forty-one Objects are in category 4 (Unique - Iconic Objects). Fifteen of these Objects are in transport category A (severe potential for damage) and eight of these in condition category 1. This means that eight unique Objects are in very poor condition and can only be moved with "severe potential for damage" – this includes the Gustafson's, Schetelig's and the 4th sledge, and the wagon. (See Appendix 3 for details on the assessment of Objects).

The Oseberg and Gokstad Ships and Objects were in 2011 placed on UNESCO World Heritage tentative list[9].

[9] http://whc.unesco.org/en/tentativelists/5577/.

The result of the assessment has been used as input to the evaluation of risk and effect in the assessment of what risk should be considered acceptable in relation to the possible relocation of the Viking Ships and Fragile Objects in the Viking Ship Collection at Bygdøy in Norway.

The likelihood of damage to an Object is influenced by the size, state and complexity of the Object. Condition, type of support/mount required and number of people required to move the Object will therefore influence the protection needed in order to avoid or minimize the likelihood of damage. Uniqueness will influence the level of effort/actions that will have to be put in place in order to achieve an acceptable level of risk.

3.2 Acceptance criteria are based on a combination of risk and uniqueness

Uniqueness has been chosen as a distinguishing factor in the assessment of what should be acceptable risk. Uniqueness as a differentiating factor has allowed the Expert Committee to make an objective assessment of the overall impact a potential unwanted event may have on the Collection.

The use of uniqueness does not necessarily capture all aspects of value but reduces the likelihood of making a decision based on conflicting values. Impact from a risk on the overall value of the Viking Ship Assemblage is in many aspects dependent on the uniqueness of the objects subject to the risk. Unique Objects are vital in ensuring that the overall value of the Viking Ship Assemblage is maintained. This implies that the greater the uniqueness of an Object, the lower the risk acceptance.

The acceptance criteria will thus be functions of the physical, biological and chemical changes that may be inflicted on the Objects as a result of potential unwanted events and the uniqueness of the Objects subjected to these changes. This relation can be expressed as a combination of risk and uniqueness:

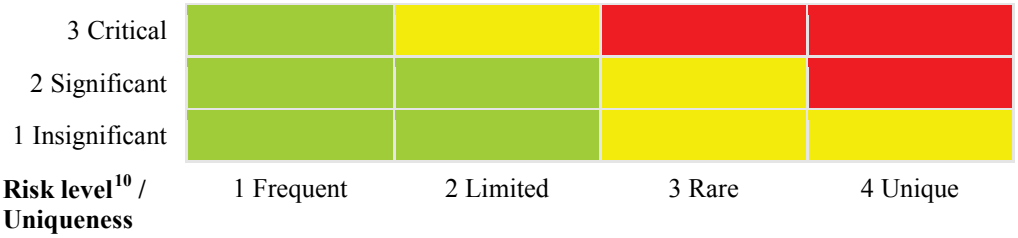
Damage Risk
=
probability that a hazard will cause an undesired effect in specified conditions and within a specified time frame and the potential extent of the damage
(see more on damage risk in chapter 4.1)

Probable impact on values
=
Combination of the damage risk to the Objects and the uniqueness of the Object affected by the risk

Total risk thus consists of:

- Probability of an undesired event
- Potential damage from the event
- Uniqueness of the Object impacted by the event

Acceptance criteria are based on a combination of damage risk level (vertical axis) and uniqueness (horizontal axis) in the matrix below.



Effect classification:	1 Acceptable	2 To be avoided	3 Unacceptable
	Acceptable, process does not require additional actions to be undertaken	Should be avoided, all possible precautions shall be investigated before the process is undertaken	Unacceptable, the process must be redesigned to mitigate risk or be abandoned

3.2.1 Elements considered when evaluating risk and uniqueness

Combining the principles of completeness and uniqueness:

- Impact is evaluated based on both the Objects in themselves and their role as part of the Viking Ship Assemblage.
- Unique Objects are given priority to ensure the value for the Viking Ship Assemblage as a whole.

Redundancy of information:

- Loss of part of the material from the Ships should be acceptable when this information can be found in other parts of the Ship.
- Retaining the shape of the object is a priority.

Structural repetitiveness:

- Risks must be minimized but some loss of repetitive patterns may be tolerated.
- However, repetitive patterns can provide information about how the Object is made.

Reconstructed parts:

- Reconstructed parts are less important but can have a value in themselves in the collection history of the Viking Ship Assemblage, depending on age and history of reconstruction.

Completeness of the Viking Ship Assemblage and completeness of the Objects:

- Objects are evaluated as part of the Collection, as loss of a part of the assemblage reduces the overall value of the Viking Ship Assemblage. As an assemblage the value of the unique objects cascades onto the less unique objects in the assemblage. Unique objects are given priority to minimize the loss of value of the assemblage.
- A small change in the completeness (loss of parts) of an already incomplete object is less significant than the same change to a complete object - regardless of the part that falls off.

[10] For overview of Risk levels see Figure 4-1

- To lose a small part of an incomplete object may be acceptable regardless of its uniqueness. NOTE - In this context no object is entirely complete - they have all changed over time.

4 RISKS ASSOCIATED WITH RELOCATION OF THE VIKING SHIPS AND FRAGILE OBJECTS

The Mandate of the Expert Committee states that the Expert Committee shall:
Carry out a comprehensive assessment of the risks related to a possible relocation of the Viking Ships and Fragile Objects.

This statement has been operationalized by the Expert Committee as:
Carry out a holistic assessment of the risks associated with relocation of the Viking Ships and Fragile Objects

4.1 Risk assessment principles used by the Expert Committee

The Canadian Conservation Institute risk management framework[11] has been used as a basis for structuring the risk picture and to clarify the evaluation process. This framework provides a structured list of hazards and general mitigating actions related to conservation of objects. The framework has been adapted to the specific challenges of this analysis. An overview of the resulting risk assessment matrix used in the risk evaluation process and a complete list of all risks identified by the Expert Committee are provided in Appendix 5.

Risks related to the conditions specific to each of the Scenarios have been identified and assessed based on evaluation of potential hazards in each phase of each Scenario and the likelihood/probability that this may lead to undesired changes in the Viking Ships and Objects, either during the project (short term) or within the next 100 years after the project (long term).

Damage Risk
=
probability that a hazard will cause an undesired effect
in specified conditions and within a specified time frame and the extent of the damage

[11] http://www.cci-icc.gc.ca/

Table 4-1 Consequences of potential events have been evaluated against the following consequence classes:

Consequence category		Description
1	Superficial damage	Repair possible with no or very little effect on the Object. Repair not visible or hardly visible. No loss of material. Future stability not likely decreased.
2	Minor damage	Object can be repaired without significant effects on the Object. Repair may be visible, but not extensive. No or very little loss of material expected. Future stability slightly decreased.
3	Significant damage	Damage where repair is possible, but not without significant influence on the Object. Some loss of material may typically occur. Very likely to decrease future stability[12] of the Object.
4	Extensive damage/total loss	Object is not possible to repair and/or significant loss of material due to disintegration of wood or other material. Severely decreases future stability of Object.

For a detailed description of the risk assessment scale for physical, biological and chemical change, please refer to Appendix 4.

The probability that an event will occur has been assessed in two time frames;

- probability of damage during the project phase of a given Scenario (short term)
- probability of damage in the next 100 years after the project (long term)

Individual risks may be specified to only impact part of the assemblage, the probability category still applies.

Table 4-2 Probability of damage has been assessed using the following scale (Moving process should be understood as the move of the total assemblage)::

Probability category		Description
1	Damage possible	Corresponds to a probability above 10%. An event may occur in one out of ten moving processes.
2	Damage unlikely	Corresponds to a probability between 1% and 10% An event may occur in one out of ten to one out of a hundred moving processes.
3	Damage rare	Corresponds to a probability between An event may occur in one out of a hundred to one out of a thousand moving processes.
4	Damage extremely rare	Corresponds to a probability less than 0.1% in less than one out of a thousand moving processes.

[12] Ref D-02.01 *In the descriptions above, the term "stability" has been used. By "reduced stability" we mean that there is an increased probability of future damage to the objects, e.g. by cracking and pieces falling off. This affects the future lifetime of the objects.*

This gives the following risk assessment matrix:

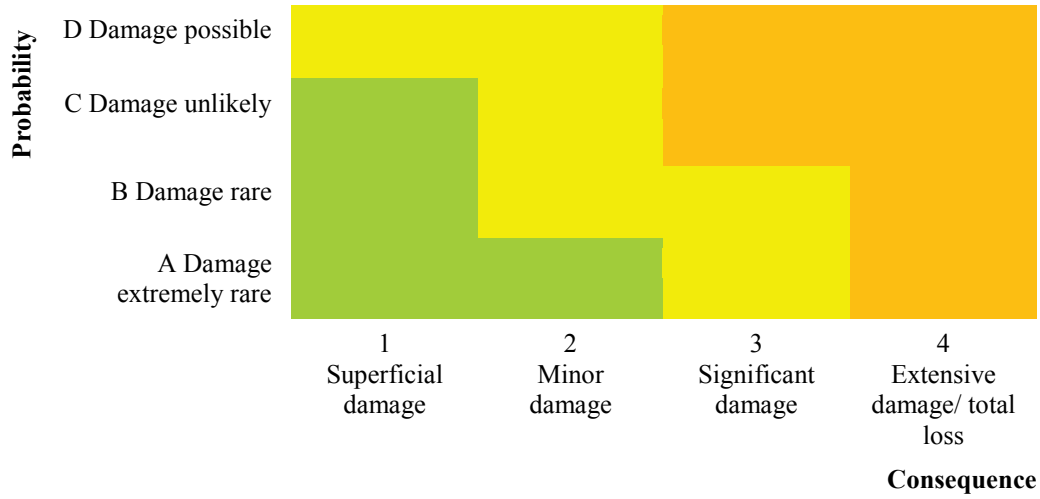


Figure 4-1 Risk assessment matrix. (For more information see Appendix 4)

4.1.1 Uncertainty in the risk assessment of the scenarios

Each scenario is considered to be uncertain due to limited knowledge. It is not possible to exactly describe the future outcome. These uncertainties will affect the risk level in ways that are currently unforeseeable.

The uncertainty of some scenarios is larger than others. This is taken into consideration when evaluating the risk.

Uncertainty is evaluated on the following simplified scale:

Table 4-3 Uncertainty evaluation scale

Uncertainty level	Description
LOW	Few or no uncertain factors impacting the risk level
MEDIUM	Some uncertain factors impacting the risk level
HIGH	Many uncertain factors impacting the risk level

4.2 Results of the risk assessment process

Based on a study of previous reports and a thorough assessment of the hazards and potential events related to each of the different Scenarios, the Expert Committee has established an overall framework for assessing the relevant risks.

Each risk has been assessed in terms of its potential consequence and likelihood of occurring in each of the Scenarios in the short term (during the projects) and the long term (within 100 years after the project is completed). The evaluated risks are then ranked based on their criticality. This gives an aggregated risk picture for each Scenario. The Expert Committee has not evaluated risks for each Object in each Scenario. This should be done as part of the detailed planning process, at which point the uniqueness (as defined in chapter 3.1) can be taken into account.

Figure 4-2 shows the aggregated risk picture for each Scenario after the risk evaluation. Each column represents an alternative. A high column indicates higher cumulative risk. Critical risks are red, significant risks are yellow and insignificant risks are green.

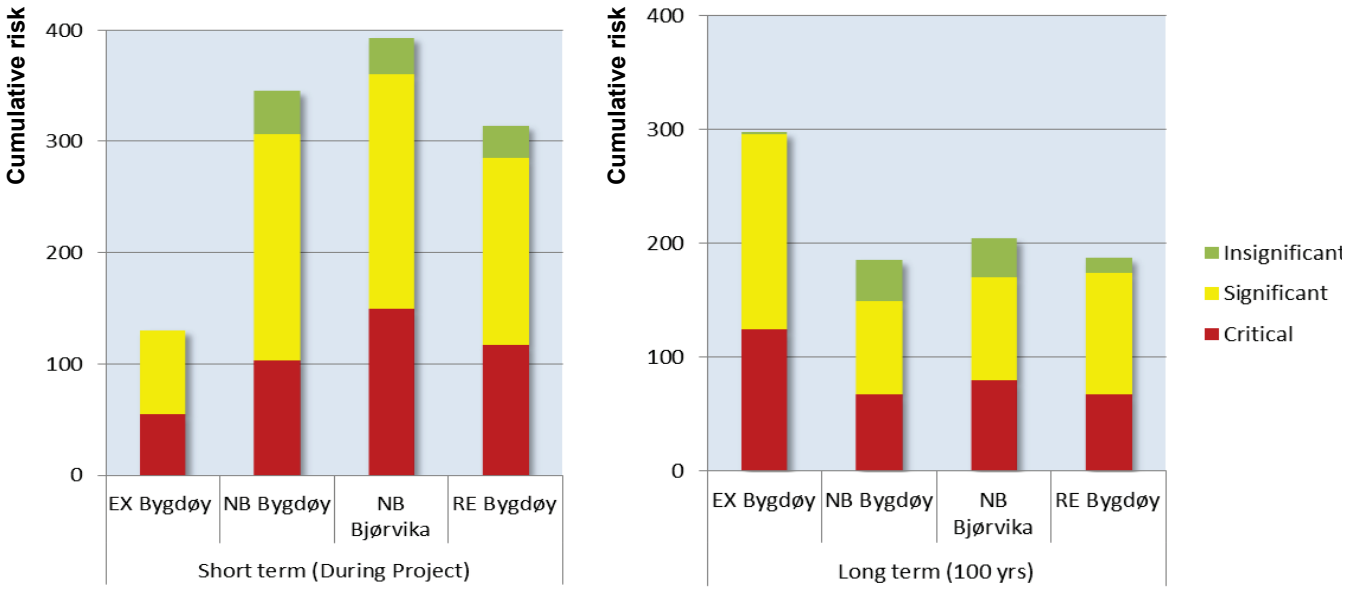


Figure 4-2 Results of the risk assessment process. The columns represent the aggregated risk picture related to each Scenario.

4.2.1 Assessed risk related to Scenario 0 – Remain in existing building at Bygdøy, no actions are taken (EX Bygdøy)

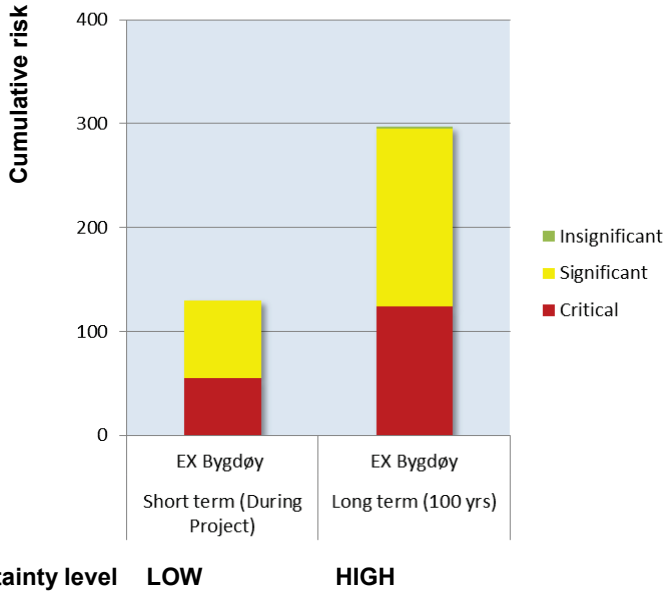


Figure 4-3 Aggregated weighted risk picture for Scenario 0, EX Bygdøy.

This Scenario has a lower short term risk level than the other Scenarios, but due to the visitor flow, security, climate and the display conditions in the existing building the risk level in the longer term is higher. Long term uncertainty in this Scenario is also high due to the age of the building.

4.2.2 Assessed risks related to Scenario 1 – New Building at Bygdøy followed by refurbishment of the existing building (NB Bygdøy)

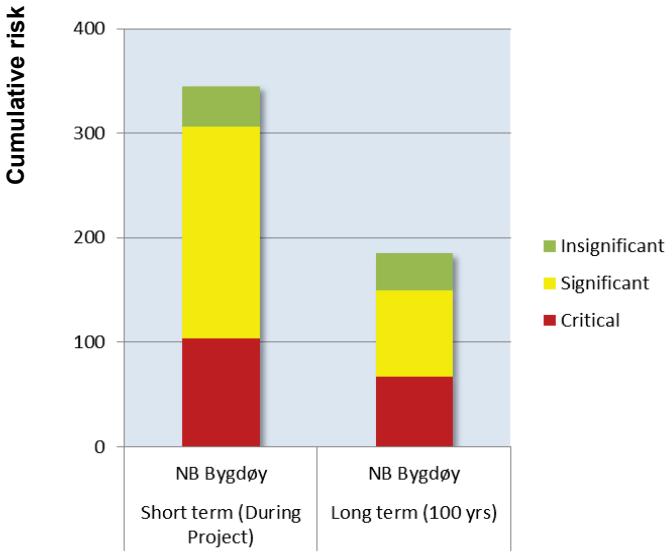


Figure 4-4 Aggregated risk picture for Scenario 1, NB Bygdøy

Building a new building at Bygdøy will increase the short term risk compared to doing nothing. There are many short term uncertainties related to this Scenario as the actual building concept for Bygdøy has not been finalized. The most critical short term risks are related to direct physical impact on the Objects during construction, e.g. vibration from construction work on the new building and potential accidents or vibration during the preparation and relocation of selected Objects into the new building.

Protecting the Objects from outside influences during construction and the process of preparation and moving the Objects into the new building requires contact with the Objects, which in itself is a risk for the most Fragile Items.

The Expert Committee has based the risk evaluation on the assumption that the existing building will be refurbished after the new building is finished as described in chapter 2.3.2. Some Objects will be moved into the new building, but there is uncertainty regarding whether larger Objects should be moved into the new building before refurbishment of the old building or must be protected in situ.

The largest uncertainties are related to the ground preparation needed when constructing the new building, how the new building will be connected to the existing building and if the risk of moving Objects temporarily into the new building while the existing building is being refurbished can be adequately managed.

If a concept is chosen that minimizes the need for ground work in preparation for the new building and also provide a good basis for protecting the Objects during refurbishment of existing building, the risk level will be lower than indicated. If a concept is chosen that will require blasting of bedrock, the short term risk will be higher than indicated.

The identified long term risks in Scenario 1 are lowest of all the concepts and are significantly lower than for Scenario 0. A new building at Bygdøy is expected to reduce the long term risk level for the Objects and improve the basis for managing the Collection long term. Bygdøy is considered to provide

an environment with less long term uncertainties related to the museum compared to the Bjørvika alternative.

4.2.3 Assessed risks related to Scenario 2 – Refurbish and remain in existing building at Bygdøy (RE Bygdøy)

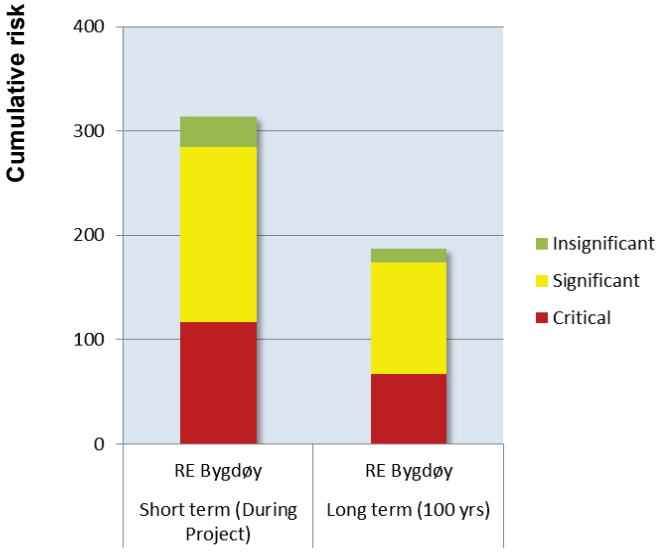
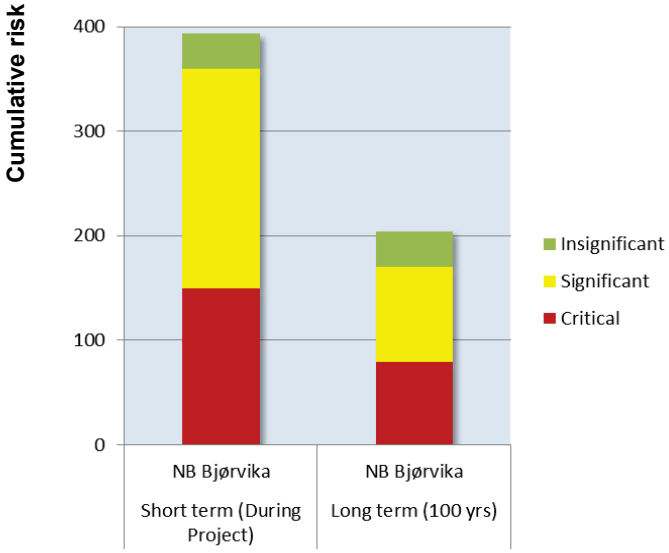


Figure 4-5 Aggregated risk picture for Scenario 2, RE Bygdøy

The identified short term risks in Scenario 2 are similar to those for Scenario 1. There are some uncertainties regarding what refurbishment is needed. However some construction work must be expected in order to improve the conditions in the building. This concept requires protection of the Objects in situ before construction work starts. The most critical risks are related to impacts from site preparation, construction work and accidents during refurbishment, e.g. vibration, falling objects or collision between construction equipment and the protective cases around Objects. As the most Fragile Objects are expected to be in situ during the refurbishment, there will be a long exposure time that increases the likelihood of accidents occurring. The process is expected to reduce the long term risk compared to doing nothing. As the existing building has limited flexibility regarding the display conditions, the long term risks are considered to be slightly higher than for Scenario 1.

4.2.4 Assessed risks related to Scenario 3 – Relocation to new building in Bjørvika (NB Bjørvika)



Uncertainty level **HIGH** **HIGH**

Figure 4-6 Aggregated risk picture for Scenario 3, NB Bjørvika

The identified short term risks related to moving the Objects to a new building in Bjørvika are similar but higher than in Scenario 1. The risk assessment indicated that the advantages of being able to finish the building in a separate location before moving the Objects does not outweigh the increased risk related to the actual packing and moving of the Objects. The distance from Bygdøy to Bjørvika increases the risks and uncertainties related to moving the Objects. Even if the proposed protective measures are implemented there will still be significant uncertainty related to the details of the transportation and actually performing the method as planned. The longer time and greater distance travelled will influence the level of risk to the Objects. The uncertainties related to external factors and transport options may add to the risk.

The identified long term risks in Scenario 3 are higher than for Scenario 1 and 2. New external infrastructure planned in Bjørvika, including rail and tram routes, new buildings, and traffic by sea or land, increases the risk level and leads to uncertainties for the concept from a long term perspective.

5 RECOMMENDATIONS ON DECISION RELATED TO FURTHER MANAGEMENT OF THE VIKING SHIPS AND FRAGILE OBJECTS

The Expert Committee has evaluated the results from the risk assessment with relevant mitigating measures to reduce the risk level (Appendix 5 and 6). The decision tree below has been used as a basis for the discussion on recommendations for further management of the Viking Ship Collection.

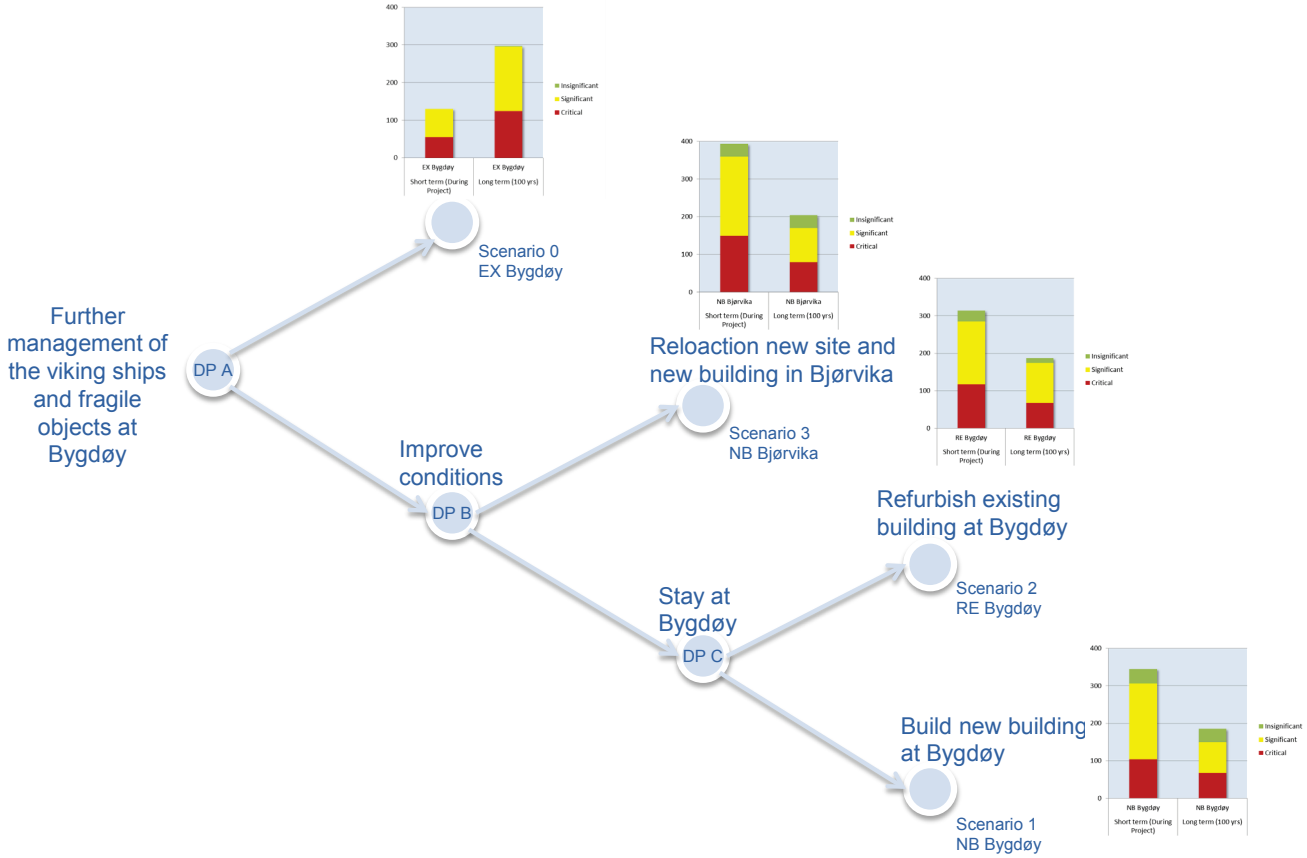


Figure 5-1 Decision breakdown with risk evaluation short and long term for each Scenario

The evaluation of uniqueness shows that the Objects in the Collection are unique from both a Norwegian (national) and international perspective (ref chapter 3.1). This means that events that may occur will potentially impact Objects that are considered to be unique.

Every Scenario has risks that are considered to be critical. None of the Scenarios that are proposed for improvement of the conditions can be completed without what the Expert Committee considers to be critical short or long term risks. A key aspect is to carefully design and execute the project to account for the identified risks and minimize risk and uncertainties.

Based on the evaluation of the risks and uncertainties related to each of the four Scenarios, the Expert Committee recommends the following:

5.1 Decision point A: Do nothing versus improve the conditions for the Viking Ship Collection.

The risk evaluation shows that the long term risks are greatest by doing nothing (ref Figure 4-2). Improving the conditions will lead to higher risk during the project execution. However, the long term risk will be significantly reduced in all Scenarios except Scenario 0. Scenario 0 will by default be a decision in favour of a long term decline of the Collection. The Expert Committee also expects that by not making a decision to take action to improve the conditions now, the problem will have to be revisited again in the near future (and repeatedly until improvements are made). The Expert Committee considers the long term uncertainty in Scenario 0 will be higher than the other Scenarios due to the status of the building in terms of security, visitor flow, climate, radiation and pollution.

The Expert Committee therefore recommends that actions are taken to improve the conditions for the Viking Ship Assemblage.

5.2 Decision point B: Move to new location in Bjørvika versus stay at Bygdøy

The risks related to the relocation to Bjørvika (Scenario 3) are higher than for the two scenarios that see the Viking Ships stay at Bygdøy, both in the short term and in the long term. In addition the short and long term uncertainties related to relocating the museum to Bjørvika are significant. The construction of a rail tunnel below or close to a new museum building followed by the rail traffic might impose further complications when creating a vibration-free environment for the Viking Ship Assemblage.

The Expert Committee considers that unknown factors related to the relocation to Bjørvika will pose potential additional risk to the physical state of the Viking Ships and Objects. Staying at Bygdøy allows the greatest flexibility in choosing the path with minimum risk in the detailed planning when making improvements to the conditions for the Viking Ship Assemblage.

The Expert Committee therefore recommends that the Viking Ship Assemblage stay at Bygdøy.

5.3 Decision point C: Build new building at Bygdøy versus refurbish existing building at Bygdøy

The short term risks related to the two alternatives are more or less the same. Building a new building at Bygdøy has some uncertainties that may reduce or increase the risk picture, depending on what building concept is chosen. A larger building is likely to increase the need for site preparation and thereby increase certain risks, e.g. vibration propagating to the museum objects. From a long term perspective, the risks for the two scenarios are more or less the same, and staying at Bygdøy minimizes uncertainties related to external factors. Refurbishing the existing building does not allow the same flexibility in choosing the minimum risk path during detailed planning to make improvements to the conditions for the Viking Ship Assemblage.

The Expert Committee therefore recommends that a new museum building for displaying of Historical Objects related to the Viking age including selected objects from the museum at Tullinløkka should be built at Bygdøy in the vicinity of the existing building, followed by a refurbishment of the existing building as part of the development of the new museum complex.

6 RECOMMENDED PRACTICAL IMPLEMENTATION OF A POSSIBLE RELOCATION

The Mandate of the Expert Committee states that the Expert Committee shall:
If relocation is acceptable, assess and recommend practical implementation of a possible relocation and visualize all the aspects of a removal process.

This statement has been operationalized by the Expert Committee as:
Assess and recommend practical implementation of the improvement of the display conditions (safe transport is included). Three Scenarios are to be evaluated – relocation to a new building in Bjørvika, a new building at Bygdøy and remaining in the existing (refurbished) building at Bygdøy.

6.1 Identified top risks

Based on the risk assessment process, nine top events were identified, see table below. The identified risks were linked to the relevant top events, establishing a basis for the discussion on risk-reducing measures for each Scenario. This is used to build the basis for the recommendations on practical measures needed in order to implement the recommended Scenario with a minimal level of risk.

Hazard	Name
Direct physical forces	Major structural deformation and/or loss of material on alum preserved Objects
Direct physical forces	Major structural deformation and/or loss of material on Viking Ships
Thieves, Vandals, Displacers	Objects are stolen, vandalized or misplaced
Fire	Fire causes scorching or smoke deposits on Objects
Water	Water spill on objects leads to deformation, staining or breakdown
Pests	Pests gain access to Objects
Contamination	Dust, pollen or gas contaminate Objects
Radiation	Lack of UV filtering in lights or windows expose Objects to radiation
Incorrect Temperature or Relative humidity (RH)	Objects are exposed to significant fluctuations or deviating temperature or relative humidity

The risk assessment process shows that Direct Physical Forces constitutes the major hazard for the objects in the short term. The Expert Committee has discussed measures related to all the top events, but the main focus has been on identifying measures to reduce the likelihood of events related to impact from direct physical forces on the Objects (see Appendix 6 for more details).

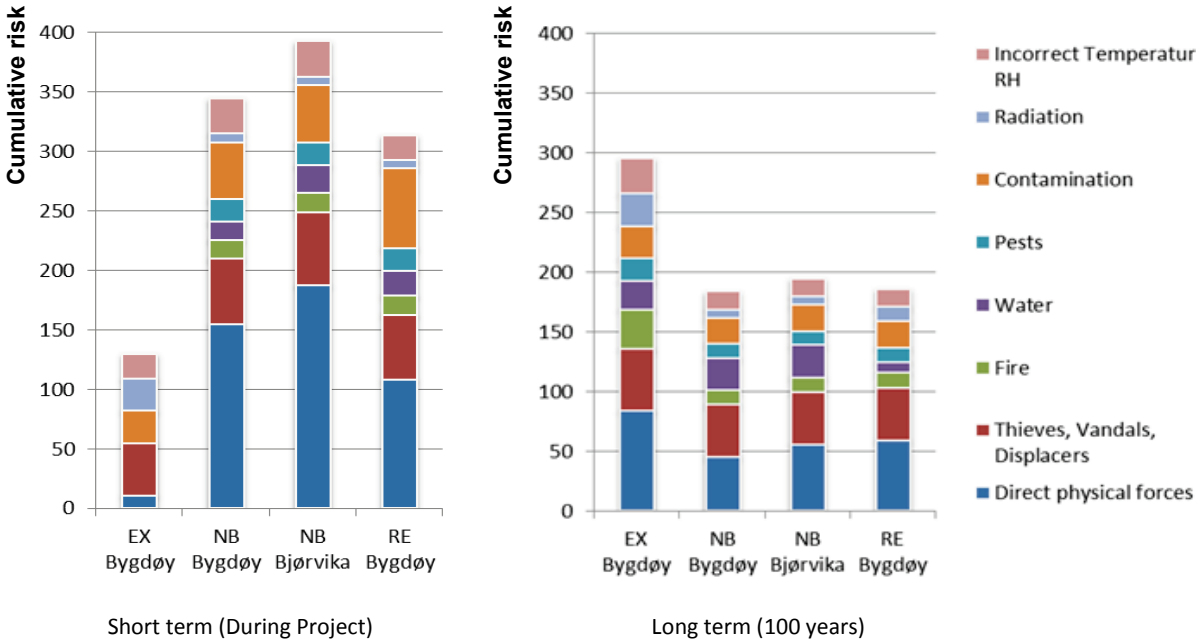


Figure 6-1 Short and long term risks per Scenario grouped per Hazard type

In addition to the mitigating actions proposed in previous studies, and included in the previous concept evaluation[13], the Expert Committee has identified the following mitigating actions:

- Complete X-ray scanning of Objects in addition to the Ships to identify weak and strong parts in the Objects
- Structured-Light scanning of object surface (3D scanning) to create a complete digital surface model of Ships and Objects
- Laser monitoring to identify structural deformation on Viking Ships, including threshold warnings, allowing immediate corrective actions

Efforts must be focused on minimizing the likelihood of damage, i.e. implementing actions that reduce the probability of damage to the Ships and Objects.

Corrective actions to be taken should risk mitigating action fail and damage occur to objects

Corrective actions should not be a main strategy for risk reduction. These should be prepared for but only be implemented if the risk reducing actions fail.

- Repair and conserve damaged Objects after relocation if needed.
- Create replica based on 3D scan model if major irreparable damage occur. (Only relevant as a last resort)

An overview of the major events that have been evaluated, with causes and related barriers is presented in Appendix 6.

[13] D-101: KS1 by the KHM, D-102: Basis for KS1

7 COSTS RELATED TO PRACTICAL IMPLEMENTATION OF THE IMPROVEMENTS, INCLUDING STABILISATION AND REPAIR

The Mandate of the Expert Committee states that the Expert Committee shall:
Calculate all costs related to moving Ships and objects, including the repair of damage to Ships and Objects.

This statement has been operationalized by the Expert Committee as:
Calculate the relevant costs related to recommended practical implementation of a possible relocation, including stabilisation and repair.

The Expert Committee's evaluation of costs related to practical implementation of the improvements is based on the risk-reducing measures proposed by the Expert Committee. Cost estimates for various alternatives have been developed for the Conceptual Evaluation of the Cultural History Museum, both by the Cultural History Museum staff and by external quality assurors[14]. Aggregated cost estimates were calculated by the Museum for a possible relocation of the Viking Ship Assemblage. The estimates were based on non-binding cost estimates from various relevant contractors with experience from packing and transportation of large and fragile Objects. The Expert Committee has reviewed both these cost estimates in relation to the mitigating actions proposed by the Committee. However due to the level of detail in the concept evaluation the Expert Committee considers that a detailed comparison of the cost assessment cannot be made.

The Expert Committee do not expect that there will be significant differences in the costs for Scenarios 1-3. The move to Bjørvika (Scenario 3, NB Bjørvika) is expected to be most expensive. Remain in the existing building at Bygdøy with no additional actions taken (Scenario 0, EX Bygdøy) is expected to be less expensive than Scenarios 1-3, but is likely to lead to longer term on-going costs to repair and conserve Objects.

There are many uncertainties regarding the actual details of the concept. However, based on the risk evaluation (Appendix 5 and 7) and the key mitigating actions (Appendix 6) the Expert Committee has the following comments:

- Based on experience the Expert Committee considers a reasonable estimate for preparing and moving the Ships and Objects to be up to 10% of the total cost of building works.
- The Expert Committee therefore considers that the cost of preparing and moving the Ships and Objects has been underestimated in both the reports[15].
- The Expert Committee cannot find indications that the cost of restoration has been included in the reports. The risk of major or irreparable damage to an object should not be underestimated. The cost of restoration is closely linked to the ability to reduce risk during the project. 3D scanning allows documentation of the loss to the Viking Ship Assemblage. It also allows the possibility to create replicas of items with irreparable damage.
- Temporary storage for the Objects at Bygdøy during building refurbishment has not been included in the relevant Scenarios.

[14] D-101: KS1 by the KHM, D-102: Basis for KS1
[15] D-101: KS1 by the KHM, D-102: Basis for KS1

- The Expert Committee has evaluated the process based on the premise that Objects should be put back on display within two years after the project.
- Based on experience the Expert Committee considers that a success criterion for the project is that key items in the assemblage should be available for display to the public within a period of two years after the project. This means that the planning of any alternative should take into account that restoration of key Objects and returning them on display should be possible within this time frame.
- After project finish adequate resources (e.g. competence, facilities, budget, tools and material) must be made available to repair any damage occurred to the Objects and returns the Objects on display to the public within an acceptable time frame.
- The cost of the different longer term effects of the Scenarios in terms of the on-going need to restore the Viking Ships and Objects must be taken into account.

8 CONCLUSIONS AND SUMMARY OF RECOMMENDATIONS

8.1 Conclusion 1: The Viking Ship Assemblage is recognised as unique and valued both in a Norwegian and international context

In its assessment of acceptable and unacceptable risks, the Expert Committee has chosen uniqueness and iconic status as the characteristic factor.

The Committee assessed the Viking Ships and what is recognised as the most important and fragile parts of the related Assemblage (fifty-six Objects). The Committee concludes that at least forty-one Objects of the Viking Ship Assemblage are unique and have iconic status both in a Norwegian and international context. This is confirmed by other international researchers consulted by the Committee. This view is further supported by the fact that the Oseberg and Gokstad Ships, and associated Objects, are part of the proposal: VIKING MONUMENTS AND SITES/Vestfold Ship Burials and Hyllestad Quern stone Quarries, nominated for inscription on the UNESCO List of World Heritage sites.[16]

Of the forty-one unique Objects, fifteen are in a poor or very poor condition and can only be moved with a severe potential risk of damage. Only three Objects are considered to be in a good condition. The Committee moreover concludes that the potential for irreparable damage is unacceptable but may be unavoidable when handling the Objects. However some form of handling of the Objects will be necessary in all Scenarios in the short or long term.

8.1.1 Recommendation 1

The Committee recommends that as a part of any further projects with the Viking Ship Assemblage, careful documentation of all Objects using state of the art analytical and measurement tools such as X-ray examination and 3D-laser scanning following best practice in the field should be initiated. If any change occurs to the Objects in the future, careful documentation will allow for repair and reconstruction.

[16] which can be found on the UNESCOs World Heritage Sites tentative list
http://whc.unesco.org/en/tentativelists/5577/

8.2 Conclusion 2: Top risk is direct physical forces

Of the nine identified top risks, direct physical forces causing structural deformation and or loss of material from the Viking Ships and alum conserved Objects are the major short term hazard.

8.2.1 Recommendation 2

A key aspect before any action on moving, relocating or securing and protecting the Viking Ship Assemblage is to design carefully, rehearse and execute each step in the project taking into account the identified risks in order to minimize uncertainties.

8.3 Conclusion 3: Lowest risk Scenario long term is development of a new museum complex at Bygdøy

Every Scenario evaluated by the Committee has risks associated with it that are considered to be critical. None of the Scenarios that are proposed to improve conditions can be completed without what the Committee considers to be critical short term risks or critical long term risks.

Based on the comprehensive risk analysis carried out by the Committee, the construction of a new building at Bygdøy followed by refurbishment of the existing building, has the lowest long term risk for the Viking Ship Assemblage, while relocating or moving the Collection will create a higher risk in the short term compared to doing nothing.

However, by delaying the decision and therefore any action, the conservation and presentation benefits that would accrue at a later stage will be diminished as the Viking Ship Assemblage will have suffered further decay and change.

8.3.1 Recommendation 3

The Committee therefore recommends that a new museum to display the Viking Ship Assemblage should be built at Bygdøy in the vicinity of the existing building followed by refurbishment of the existing building as part of the development of a new museum complex.

8.4 Conclusion 4: A new museum complex at Bygdøy will improve long term preservation of the Viking Ships Assemblage

Although the current indoor climate does not impose a high risk in terms of chemical and biological decay, the improvements to the environment and display conditions that a new or refurbished museum building offer will improve the long term preservation of the Viking Ships Assemblage.

8.4.1 Recommendation 4

When designing the new museum and refurbishing or improving the existing display environment, every effort must be made to create conditions for object preservation and no space housing the Viking Ships or Assemblage should be climatised for human comfort rather than for the long term preservation of the Objects.

8.5 Conclusion 5: Possible restoration works and long term costs for maintenance and care of the collection should be considered

The costs for documenting, preparing and moving the Viking Ships and/or parts of the Assemblage, followed by possible restoration works and preparing new and safe display must be added to the existing estimates of costs. Based on experience, it is estimated that these costs can be up to 10% of the total cost of building a new museum complex. Moreover long term costs for maintenance and care of the Collection should be considered.

8.5.1 Recommendation 5

After project completion, adequate resources must be made available to repair (any) damage that has occurred to the Objects, including the necessary time for carrying out restoration and display work before opening to the public. The long term resources and costs for maintenance, monitoring, preventive conservation initiatives and carrying out restoration works on the Viking Ships Assemblage must also be estimated.

APPENDIX 1
REFERENCE DOCUMENTS

This Appendix provides an overview of documents evaluated by the Expert Committee as input to the evaluation process.

#	Translated description project/document	Description project/document	Ordered by	Made by	Date	Why it was commissioned	Language
D-01	**New museum of cultural history in Bjørvika**		**Government**		**1999-?**	**KHM needs new locations**	
D-01.01	New museum of cultural history in Sørenga, Visions and premises	Nytt kulturhistorisk museum på Sørenga, Visjoner og premisser	The Board of UiO	UiO (Universitet in Oslo)	27.03.2000	Clearify visions and condisions for the new museum.	NO some in ENG
D-01.02	Observations and Recommendations Resulting from Study Sessions with the Staff of the Cultural History Museum in the UiO	Observations and Recommendations Resulting from Study Sessions with the Staff of the Universitetets Kulturhistoriske Museer Oslo, Norway	KHM (Kulturhistorisk museum)	Robert Barnett President Cultural Innovations Ltd (UK)	03.05.2003	Recommendations from an expert: How to transfer visions to plans for a new modern museum? What about the Viking ships?	EN
D-01.03	Museum Workshops 1-5: 1. What will the museum be in the 21 century? 2. What kind of audience will the museum have and how will the museum fulfill the various groups' interests? 3. What "stories" shall we tell? 4. How shall we tell the "stories"? 5. The requirements for preservation in the new museum	Museumsseminarer 1-5: 1. Hva skal museet være i det 21. århundre? 2. Hvilke målgrupper skal museet ha og hvordan skal museet ivareta de ulike gruppenes interesser? 3. Hvilke "historier" skal vi fortelle? 4. Hvordan skal vi fortelle ”historiene” ? 5. Kravene til bevaring i det nye museet	KHM	KHM	2003-2005	Collect inspiration and recommendations from other museums and experts	NO
D-01.04	Report - Measurements of vibrations and assessment of requirements with measures, Bjørvika	Vibrasjonsrapport - Bjørvika	Statsbygg	Brekke og Strand	June 2005 (not 2004)	Consider vibrations from the trains and trams in Bjørvika	NO some in ENG
D-01.05	Fact Sheet 01 - Cultural History Museum 02 - Build Historical overview 03 - History: KHM in Bjørvika 04 - KHM and the Medieval age park 05 - The Viking Ship Museum as a museum building 06 - Why move Viking ships 07 - Exhibitions and activities in the new museum	Faktaark 1 - Kulturhistorisk museum 2 - Bygghistorisk oversikt 3 - Historikk: KHM i Bjørvika 4 - KHM og Middelalderparken 5 - Vikingskipshuset som museumsbygning 6 - Hvorfor flytte vikingskipene 7 - Utstillinger og aktiviteter i det nye museet	KHM	KHM	June 2007	Communicate "facts" about the new museum in Bjørvika: The history of the museum. What is not working today, and how will the museum in Bjørvika be with the Viking ships	NO

#	Translated description project/document	Description project/document	Ordered by	Made by	Date	Why it was commissioned	Language
D-01.06	Reflection: Number of Visitors to Bjørvika	Betenkning: Besøkstall vikingskipene i Bjørvika	KHM	Associate Professor Arvid Flagestad *	22.02.2010	Verify the estimate of number of visitors in a new museum	NO some in ENG
D-01.07	Cultural History Museum: Bygdøy - Bjørvika History - a collection of Cultural History Museum	Kulturhistorisk museum: Bygdøy – Bjørvika Historikk – et samlet Kulturhistorisk museum	UiO	KHM	05.04.2010	Why it is important for the museum to be consolidated in Bjørvika	NO
D-02	**Preliminary risk evaluation of movement of Viking ships collection**		**The Board of UiO**	**UiO**	**2001-2003**	**Shall UiO recommend moving of the Viking ship to the new museum?**	
D-02.01	VIKING SHIP MUSEUM - Risk Evaluation of the Move of the Collections with App A, B and C (ANNEX): *A in EN* : Details of risk analysis of objects *B in NO:* Alternative transportations routes of ships *C (ANNEX) in EN:* Transport of Viking Ships to a New Location – Oseberg Ship Case Study	VIKING SHIP MUSEUM - Risk Evaluation of the Move of the Collections with App A and B: A in EN: Details of risk analysis of objects B in NO: Alternative transportations routes of ships C (ANNEX) in EN: Transport of Viking Ships to a New Location – Oseberg Ship Case Study	UiO	Safetec	01.09.2002	Preliminary risk evaluation of moving the Viking ships collection	EN
D-02.02	An evaluation of the Condition of the Viking Age Collections at the Viking Ship Museum Part I: Objects on display in the Fourth Wing	An evaluation of the Condition of the Viking Age Collections at the Viking Ship Museum Part I: Objects on display in the Fourth Wing	UiO	KHM	2002	Conservation survey and evaluation of the objects on display in the Oseberg Wing, Viking Ship Museum	EN
D-02.03	Report: Viking ship Seminary, 14 and 15 February 2002	Vikingskipsseminaret 14. og 15. februar 2002 RAPPORT	UiO	UiO	14.02.2002	Open discussion about moving the Viking Ship Collections of prominent professionals in the field of conservation and ship history	NO or EN
D-03	**Evaluation of mooving the Viking Ships to Bjørvika or leaving them at Bygdøy**		**The Board of UiO**	**KHM**	2005-2006	**Should UiO recommend KD to relocate the Viking Ships to the new museum i Bjørvika?**	

#	Translated description project/document	Description project/document	Ordered by	Made by	Date	Why it was commissioned	Language
D-03.00.00	Board at the University of Oslo (UiO), 20 December 2006 adopted by 8 to 3 vote to go into the relocation of the Viking Ship	Styret ved Universitetet i Oslo (UiO) har 20.desember 2006 vedtatt med 8 mot 3 stemmer å gå inn for flytting av vikingskipsfunnene		The Board of Uio	20.12.2006	Recommendation from the Board of UiO to KD about relocation of the Viking Ships collections	
D-03.00.01	Relocation of Viking ships: Resolution by the Board of the Museum of Cultural History 16 October 2006	Flytting av vikingskipene: Vedtak i styret ved Kulturhistorisk museum 16. okt. 2006	The Board of UiO	The Board of KHM (4 employees, 2 external, 1 UiO, 2 Students)	16.10.2006	The Board of KHM's recommendation to the Board at UiO about relocation of the Viking ships	NO
D-03.00.02	Questions about moving Viking collections from the Viking Ship Museum to the planned new Museum of Cultural History in Bjørvika	Spørsmål om flytting av vikingskipssamlingene fra Vikingskipshuset på Bygdøy til planlagt nytt Kulturhistorisk museum i Bjørvika	UiO	KHM	16.10.2006	The Museum director's recommendation to the Board at KHM about relocation of the Viking ships	NO
D-03.01	Viking Ships - Bygdøy or Bjørvika Consequence assessment, moving of Viking Ships	Vikingskipene - Bygdøy eller Bjørvika Konsekvensanalyse, flytting av vikingskipene	The Board of KHM	KHM	october 2006	Complete evaluation of moving/not moving the Viking Ship Collections	NO ENG
D-03.02.00	Risk Analysis: Moving or storing the Oseberg Ship and Object exhibited at Bygdøy	Risikovurdering. Flytting eller lagring av Osebergskipet og gjenstandene utstilt på Bygdøy	KHM	Scandpower Risk management	06.10.2006	Complete risk evaluation of movement or storage of the Viking Ship Collections	NO some in EN
D-03.02.01	Scandpower: MoM, 26.01.2006: Summit to discuss aspects of the relocation of the Viking Ships, App A1	Scandpower: MoM, 26.01.2006: Summit to discuss aspects of the relocation of the Viking Ships, App A1	KHM	Scandpower Risk management	26.01.2006		
D-03.02.02	Scandpower: Risk Assessment: Future of the Viking Ships and Collections, App A2	Scandpower: Risk Assessment: Future of the Viking Ships and Collections, App A2	Scandpower Risk management	Jonathan Ashley-Smith	19.02.2006	Document J. Ashley-Smith` visit in Oslo and his opinion about moving the Viking Ship Collections	EN
D-03.02.03	Scandpower: Risk elements and matrix - Oseberg Ship, App B	Scandpower: Risk elements and matrix - Oseberg Ship, App B	KHM	Scandpower Risk management	18.05.2011	Risk elements and matrix - Oseberg Ship	NO

#	Translated description project/document	Description project/document	Ordered by	Made by	Date	Why it was commissioned	Language
D-03.02.04	Scandpower: Risk elements and matrix - alum-conserved objects, App C	Scandpower: Risk elements and matrix - alum-conserved objects, App C	KHM	Scandpower Risk management	18.05.2011	Risk elements and matrix - alum-conserved objects	NO
D-03.03	Relocation of the Viking Ships - Structural Report	Byggeteknisk redegjørelse	Scandpower Risk management	PTL Prosjekt og teknologi-ledelse as	04.10.2006	Substantiate the different risks from the building in the three options for Viking Ships	NO some in ENG
D-03.04	Strength analysis of the Oseberg Ship	Styrkeanalyse av Osebergskipet	KHM	Det Norske Veritas	27.02.2006	Make a model and analyze the strength of the Oseberg Ship	NO ENG
D-03.04.01	Strength test of the wood in Oseberg Ship	Materialprøver	KHM	Det Norske Veritas	26.01.2006	Document the strength of the wood in the Oseberg Ship - strength tests	NO
D-03.04.02	Mapping of damage of Oseberg Ship	Skadekartlegging av Osebergskipet	KHM	KHM	05.07.2005	Define the method to make visual map of the Oseberg ship and map out parts of the ship	NO
D-03.04.03	Wood Technological assessment of the Oseberg ship	Treteknologisk vurdering av Osebergskipet	KHM	For.kandidat Kristen Aamot	Mars 2005	Collect information about the wood in the Oseberg ship	NO
D-03.04.04	Report, Norwegian forest research institute - Dynamic MOE ultrasound	Skogforsk rapport - Dynamisk MOE ultralyd	KHM	Skogforsk Norwegian forest research institute	February 2006	Is it possible to evaluate wood stiffness with ultrasound?	NO
D-03.04.05	Report, Norwegian forest research institute - SEM microscopy	Skogforsk rapport - SEM mikroskopering	KHM	Skogforsk Norwegian forest research institute	March 2006	Can scanning electron microscope study tell anything about the oak in the Oseberg ship.	NO
D-03.04.06	Comments to Veritas Report 2005, rev 1	Kommentarer til Veritas Rapport 2005 rev 1	KHM	Wood engineer Nils Ivar Bovim	31.01.2006 (Not 2005)	Review of Veritas model from a wood-technological point of view	NO
D-03.05	**Exempt Public Access:** Report, "Object Group" (internal group) - risk assessment, moving of the Viking Ships	RAPPORT "Gruppen Gjenstander" endelig versjon 011006	KHM	KHM*	01.10.2006	Document the work done in the 'Object Group'	NO

#	Translated description project/document	Description project/document	Ordered by	Made by	Date	Why it was commissioned	Language
D-03.06	Review of selected alum preserved objects in the magazine VSH	Gjennomgang av utvalgte alunkonserverte gjenstander i magasin VSH	KHM	Sandstrøm og Strætkvern *	Nov 2005	Examine selected alum-treated objects from the Oseberg storage at the Viking Ship Museum	Scandinavian
D-04	**Quality assurance "risk for Viking ship collection" by moving to Bjørvika or development on Bygdøy**		**KD** (Ministry of Education and Research)	**UiO**	**2010**	**Part of quality assurance (KS1) of localization of new KHM**	
D-04.01	Risk assessment for the Viking Ships	Risikovurdering for vikingskipene	KD	UiO	12.05.2010	Risk assurance of the Viking ship collection	NO some in ENG
D-04.02	Risk assessment of the Viking ship Museum as regards vibrations	Risikovurdering av Vikingskipshuset vedrørende vibrasjoner	UiO	Brekke og Strand	28.04.2010	Consider vibrations in alternative locations of Viking ships	NO some in ENG
D-04.03	Risk Assessment Relating to Security on Moving viking Ships and Objects to Bjørvika, or Continued Localisation in an Up-dated Viking Ships Museum at Bygdøy	Risikovurdering relatert til sikkerhet ved flytting av vikingskip og gjenstander til Bjørvika eller fortsatt lokalisering i oppdatert Vikingskipshus	UiO	Cowi	28.04.2010	Consider the security in alternative locations of Viking ships	NO some in ENG
D-04.04	Assessment of the Building`s Tolerance on Climatisation	Vurdering av byggets tåleevne ved klimatisering	UiO	Norconsult	07.05.2010	Consider the climate in alternative locations of Viking ships	NO some in ENG
D-04.05	The transfer of the Viking Ship Collection – the professional staff's assessment of the risks and conditions	Flytting av Vikingskipssamlingen – den faglige stabens vurdering av risiko og betingelser	KHM	KHM	08.05.2010	Coordinate and document the employees ' (archaeologist and conservator) views about the relocation of the Viking Ship Collections	NO ENG
D-04.06	Valuation	Verdivuring	KHM	KHM	19.04.2010	Document the employees ' views on the localization of the new Museum include moving of the Viking Ships	NO
D-04.07	Past movements of the Viking Ship	Tidligere flyttinger av vikingskipsfunnene?	UiO	KHM	08.05.2010	Document previous moves of the Viking Ship Collections	NO

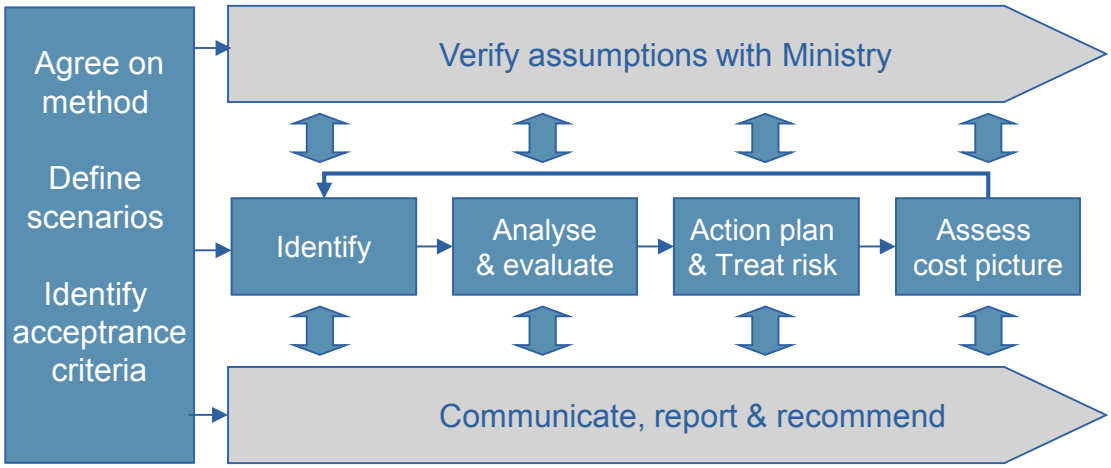
#	Translated description project/document	Description project/document	Ordered by	Made by	Date	Why it was commissioned	Language
D-05	**REVITA**		**KD** (Ministry of Education and Research)	**KHM**	**2002 - today**	**To ensure preservation, documentation and access to the collections.**	
D-05.01	Emergency protection of three magnificent sledges from Oseberg find	Nødsikring av tre praktsleder fra Osebergfunnet	KHM	KHM	2009	Design support systems for the three sleds from the Oseberg finds.	NO
D-05.02	Scheteligs slede Evaluation of X-ray study	Scheteligs slede vurdering av røntgenundersøkelsen	KHM	KHM	2007	Evaluate the condition of Scheteligs sled based on X-rays taken	NO
D-05.03	Safety measures on Schetelig sled Photo documentation	Sikringstiltak på Scheteligs slede-fotodokumentasjon	KHM	KHM	2007	Illustrate dismantling of the new support system on Scheteligs sled	NO
D-05.04	Support arrangement of the carriage from Oseberg find	Oppstøtting av vognen fra Osebergfunnet	KHM	KHM	2008	Gather information about the wagon and giving it new supports	NO
D-05.05	Packing and moving of Oseberg-Gokstad Magazine	Nedpakking og flytting av Oseberg- og Gokstadmagasinet	KHM	KHM	2010 Project period 2007-2009.	Move the objects in storage at the Viking Ships Museum to a new magazine at Økern -10 km	NO
D-05.06	Evaluate the alum-treated objects after transport from the Viking Ship Museum to new storage at Økern	Vurdering av alunkonserverte gjenstander - etter flytting til Økern magasinet	KHM	KHM	September 2011	Evaluate the alum-treated objects after transport from the Viking Ship Museum to new storage at Økern	NO
D-06	**Documents and presentations at international conferences and workshops**						
D-06.01	How to Move a Viking Ship: two conservators' perspectives on the process leading to a decision	How to Move a Viking Ship: two conservators' perspectives on the process leading to a decision	ICOM-CC WOAM (Wet Organic and Archaeological Materials)	Susan Braovac and Tone Olstad*	10.09.2007 Amsterdam	Present ate the process of "moving the Viking ship collections" in an international forum of curators	EN
D-06.02	The properties of Alum. Investigations into the environmental sensitivity of Alum treated archaeological wood	The properties of Alum. Investigations into the environmental sensitivity of Alum treated archaeological wood	ICOM-CC WOAM	J. Hutchings* UiO	10.09.2007 Amsterdam	Comparing environmental sensitivities of archaeological wood treated with PEG and with alum.	EN

#	Translated description project/document	Description project/document	Ordered by	Made by	Date	Why it was commissioned	Language
D-06.03	Is this the way to treat an Old lady? Time for reconsideration of established cleaning routines.	Is this the way to treat an Old lady? Time for reconsideration of established cleaning routines.	ICOM-CC triennial meeting	KHM	22.09.2008 New Delhi, India	Evaluate the cleaning routines and get information about the dust in the Oseberg ship	EN
D-06.04	Looking inside! 3D imaging experiments on alum-conserved archaeological wood	Looking inside! 3D imaging experiments on alum-conserved archaeological wood	Conference: Archäometrie und Denkmalpflege	KHM and Paul Scherrer Institute, Villingen, Switzerland	14.09.2010 Germany	Summary about imaging degraded wood from Oseberg.	EN
D-06.05	New materials for the preservation of archaeological wood: a task for biomimetics?	New materials for the preservation of archaeological wood: a task for biomimetics?	Workshop: regarding biomimetic materials*	KHM	May 2010 Vienna	What are the requirements and possibilities of new materials for the preservation of archaeological wood?	EN
D-06.06	The use of an electric field for the removal of alum from treated wooden objects	The use of an electric field for the removal of alum from treated wooden objects	ICOM-CC WOAM (WOAM2010_I.Christensen etal)	KHM and Denmark's Technical University.	2010 North Carolina	Can electronic field remove the alum from treated wooden objects	EN
D-06.07	Past Conservation Treatments and their Consequences – the Oseberg Find as a Case Study	Past Conservation Treatments and their Consequences – the Oseberg Find as a Case Study	ICOM-CC WOAM	KHM, UiO	2010 North Carolina	Some consequences of past Conservation Treatments	EN
D-06.08	Measurement of responses in archaeological wood to ambient temperature and relative humidity A case study - The Oseberg ship	Measurement of responses in archaeological wood to ambient temperature and relative humidity A case study - The Oseberg ship	ICOM-CC WOAM	KHM, UiO	2010 North Carolina	Measure the dimensional changes on the Oseberg ship with changes in ambient RH.	EN
D-06.09	Microstructure – stiffness relations of the ancient oak wood from the Oseberg ship	Microstructure – stiffness relations of the ancient oak wood from the Oseberg ship	Workshop COST IE0601 and FP0802	KHM and Vienna Univ. of Technology. Thomas Bader	12.04.2010 Krakow Poland	Give some background information about mechanical evaluation by Det Norske Veritas.	EN
D-06.10	Chemical composition of the archaeological oak wood from the Oseberg Ship	Chemical composition of the archaeological oak wood from the Oseberg Ship	EWCHP European Workshop and Training Day on Cultural Heritage Preservation	KHM and Vienna University of Technology*	26.09.2011 Berlin	Chemical analysis of the Oseberg ship with a discussion on how this relates to mechanical properties	EN

#	Translated description project/document	Description project/document	Ordered by	Made by	Date	Why it was commissioned	Language
D-06.11	From wood to what? Gustafson's Sled. Documentation condition and changes	From wood to what? Gustafson's Sled. Documentation condition and changes	UKMs Skrifter	UKM-Nancy Child	2002	Description of Gustafson's sled	EN
D-06.12	Preservation Challenges and potential solutions	Preservation Challenges and potential solutions	KHM	KHM	?	Describing to projects. 1. Design and test transport supports and methods for the potential move of the collections from the Viking Ship Museum to a new museum ca 6 km away. 2. Re-conservation of alum conserved objects from the Oseberg finds.	EN
D-100	**OTHER DOCUMENTS**						
D-101	**Exempt Public Access:** KS1 by the Museum of Cultural History - summary and table of contents	Exempt Public Access: KS1 by the Museum of Cultural History - summary and table of contents	KHM		2009	Part of QA 1 process for new Cultural Heritage Museum	EN Summary and table of contents
D-102	**Exempt Public Access:** UiO Basis for quality assurance KS1	Exempt Public Access UiO Basis for quality assurance KS1	KHM		2009	Part of QA 1 process for new Cultural Heritage Museum	EN
D-102.01	Exempt Public Access: Alternative Analysis for Cultural Heritage Museum	Assessment of alternatives including cost and benefits	KHM	KHM	28.05.2009	Part of QA 1 process for new Cultural Heritage Museum	NO
D-103.01	The stabilizing of wood found in the Viking ship of Oseberg, Part I	The stabilizing of wood found in the Viking ship of Oseberg, Part I		Anna M. Rosenqvist	1959	Studies in Conservation, Volume 04, pp 13-22, 1959	EN
D-103.02	The stabilizing of wood found in the Viking ship of Oseberg, Part II	The stabilizing of wood found in the Viking ship of Oseberg, Part II		Anna M. Rosenqvist	1959	Studies in Conservation, Volume 04, pp 62-72, 1959	EN
D-104	Prosjekt for dokumentasjon av de alunkonserverte gjenstander_090112. endelig versjon	Description of project to make 3D documentation of the alum preserved objects in the Oseberg find	KHM	KHM	09.01.2012	Application fro project grant	NO
D-105	Redningsplan for vikingskipshuset	Evacuation plan for the viking ship building at Bygdøy including prioritized sequence of evacuation for the objects	KHM (Kulturhistorisk museum)	KHM	17.06.2008	Part of local emergency preparedness plan	NO

APPENDIX 2
OVERVIEW OF MEETINGS AND ASSESSMENT PROCESS FOLLOWED BY THE EXPERT COMMITTEE

The evaluation by the Expert Committee has followed the process steps as illustrated in the figure below:



The expert committee has collaborated through meetings, phone conferences and mail correspondence.

The following formal meetings have been conducted in the Expert Committee

Meeting #	Topic/agenda	Deliverables
Meeting 1 22 June 2011 Oslo	**Meeting with Minister of Education and Research.** Visit to relevant sites guided by University of Oslo and key members of the Viking Ship Museum, Meeting in the Committee to plan and agree on further work process	• Agreed plan for further work • General understanding of the issues to be addressed by the Committee • Preparations needed between meetings • Proposed evaluation criteria to be investigated before Meeting 2

Meeting #	Topic/agenda	Deliverables
Meeting 2 08 December 2011 Høvik	**Workshop on acceptance criteria regarding reversible and irreversible damage.** Preparations: • Establish proposed acceptance levels and description of evaluation criteria based on international experience	• Overview of what can be accepted change to the Ships and Objects (Acceptance criteria) • Defined risk matrixes for all evaluation criteria to be evaluated in risk assessment • Preparations needed before Meeting 3
Meeting 3 3 February 2012 London	**Workshop to identify risks and assess risk level for identified risks** Preparations: • Clear description of alternative concepts to be assessed in risk workshop. First draft of visualization of aspects related to a removal process. • Structure risk evaluation criteria based on output from Meeting 2 (to be verified by Expert Committee members before Meeting 3). • Establish compiled set of potential risks with descriptions based on thorough investigation of available documents and previous risk assessments.	• Comprehensive assessment of the risks related to a possible relocation of the Viking Ships and fragile Objects and the possible new location in Bjørvika. • Ranked list of identified risks for each concept based on established evaluation criteria • Preparations needed before Meeting 4
Meeting 4 1 March 2012 Copenhagen	**Workshop to conclude on acceptance criteria and risk picture** **Conclude on practical implications of a possible relocation and the aspects of a removal process.** **Conclude on recommendations to bring forward to the Ministry of Education and Research.** Preparations: • Based on risk evaluation establish basis for recommending practical implementation of possible relocation. • Establish decision basis for determining visualization of all aspects of a removal process. • Evaluate activities and resources related to moving Ships and Objects including repair of damage to Ships and objects.	• Final conclusions and recommendations to the Ministry of Education and Research

OWNER
Ministry of Education and Research

MANAGEMENT

Ministry repre-sentative

Mandate for the Expert Committee

PURPOSE: Assess risks for three scenarios and provide recommendations to the Ministry based on what should be acceptable risk in an international context
Start: Mandate from Ministry
Stop: Recommendation to Ministry

INPUT

Preparation document

SUB PROCESS

Examine, in an international context, what is acceptable physical, chemical and biological change to the ships and objects **M2**

Carry out a holistic assessment of the risks associated with location of the Viking Ships and fragile objects. **M3a**

Assess and recommend practical implementation of the improvement of the display conditions **M3b**

Calculate all the costs related to point 3, including stabilisation and repair **M4a**

Conclude on recommendations **M4b**

OUTPUT

Recommendation on actions to Ministry

RESOURCES

Expert committee

Viking ship museum staff

Previous reports

EasyRisk Manager

OWNER:
Ministry of Education and Research

MANAGEMENT

Ministry repre-sentative

Mandate for the Expert Committee

PURPOSE: Assess risks for three scenarios and provide recommendations to the Ministry based on what should be acceptable risk in an international context
Start: Mandate from Ministry
Stop: Recommendation to Ministry

INPUT

Mandate for the Expert Committee

SUB PROCESS

Agree on method for assessment **M2.1**

Define scenarios to be assessed **M2.2**

Agree on value principles for evaluation of risk acceptance criteria **M2.3**

Establish risk evaluation matrix **M2.4**

Conclude on what should be acceptable **M2.5**

OUTPUT

Risk Matrix

Acceptance criteria definition

RESOURCES

Expert committee

Viking ship museum staff

Previous reports

EasyRisk Manager

OWNER
Ministry of Education and Research

MANAGEMENT

Ministry repre-sentative

Mandate for the Expert Committee

PURPOSE: Carry out a holistic assessment of the risks associated with location of the Viking Ships and fragile objects
Start: Acceptance criteria and risk matrix definition
Stop: Bow tie assessment of risk including barriers, controls and actions

INPUT

Risk Matrix

Acceptance criteria definition

SUB PROCESS

Identify major events to be assessed **M3a.1**

Identify potential causes for change to the objects **M3a.2**

Identify potential consequences from the events **M3a.3**

Evaluate effects and overall risk level against risk acceptance criteria **M3a.4**

Identify relevant mitigating actions **M3b.1**

Assess effectiveness of identified actions **M3b.2**

OUTPUT

BowTie model for major events with cause, consequence and actions

RESOURCES

Expert committee

Viking ship museum staff

Risk list from previous reports

Action list from previous reports

EasyRisk Manager

OWNER
Ministry of Education and Research

MANAGEMENT

Ministry repre-sentative

Mandate for the Expert Committee

PURPOSE: Conclude on recommendations
Start: Bow tie assessment of risk including barriers, controls and actions Overview of cost of mitigating actions
Stop: Recommendation on actions to the Ministry of Education and Research

INPUT

BowTie model for major events with cause, consequence and actions

SUB PROCESS

Recommend actions to be implemented in order to meet acceptance criteria **M4.1**

Assess total cost of recommended actions **M4.2**

Determine risk level after proposed actions **M4.3**

Conclude on final recommendation **M4.4**

Formulate conclusions for final report **M4.5**

OUTPUT

Recommendation on actions to Ministry

RESOURCES

Expert committee

Viking ship museum staff

Asessment of cost related to proposed actions

Draft Report to Ministry

EasyRisk Manager

APPENDIX 3
OBJECT STATUS AND UNIQUENESS EVALUATION

This Appendix gives an overview of the Objects that are considered as part of the risk assessment. This is not a complete list, but focuses on the items that are expected to be most sensitive to potential change when exposed to a possible relocation process. The list is based on the detailed assessment done in the report 'An evaluation of the Condition of the Viking age Collections at the Viking Ship Museum'[17] from 2002.

On request from the Expert Committee the Viking Ship Museum staff has supplemented the original report with an assessment of the uniqueness of the Objects based on a database containing about 50% of all archaeological finds in Norway. The database shows that there are very few archaeological excavations in Norway with well-preserved wood from the Viking Age.
To supplement the assessment by the Viking Ship Museum with an international perspective the uniqueness of the objects has been evaluated by members of the Expert Committee and by experts from the National Museum in Denmark (NMD).

The table below is used as input to the evaluation of risk and effect in the assessment of what risk should be considered acceptable in relation to the possible relocation of the Viking Ships and Fragile Objects in the Viking Ship Collection at Bygdøy in Norway.

The list is a representative overview of the Objects that may prove complicated to move. In addition to the Objects in the list, the museum also has metal objects and textiles that are not included as they are considered less complicated to move; these metal objects are considered less unique than the objects made from wood.

The likelihood of damage to an Object is influenced by the size, state and complexity of the Object. Condition, type of support/mount required and number of people required to move the Object will therefore influence the protection needed in order to avoid or minimize the likelihood of damage. Uniqueness will influence the level of effort/actions that will have to be put in place in order to achieve an acceptable level of risk.

[17] D-02.02: Evaluation of the condition of the Viking Ship Collection, KHM, UiO, 2002

The table below shows the uniqueness scale established by the Expert Committee as basis for the assessment of the Object's uniqueness

Uniqueness of the Objects:		Characteristics of uniqueness level
4	Unique - No known object of same function/type/construction/shape	Iconic object – cultural, national, historical, emotional response/value Provides unique research potential (present and future) Part of a historically unique relationship Preventive action is obligatory. Need for corrective actions only after thorough expert consultation.
3	Rare / scarce - Few objects of same type but no known objects in same state	Not unique but holds symbolic significance. Archetype - Opens up understanding about historical associations/ understanding High research potential – one of few objects available to provide knowledge and understanding in specific areas. Preventive action is obligatory. Minor corrective action acceptable (e.g. replacing rivets)
2	Limited / infrequent - Few objects of same type and some in same state	Exemplar – set point for comparison Considerable research potential – increases the opportunity/ contributes to the knowledge within specific areas Preventive action is a priority, with corrective action if necessary
1	Frequent/ extensive - Common, other objects of same type and state	Research potential adds to building a typology and understanding about use and craftsmanship within specific areas. Plays a role within the encyclopaedia of historical information Preventive action is a priority, with corrective action if necessary.

The figure below presents an aggregation of the assessment in an international context.

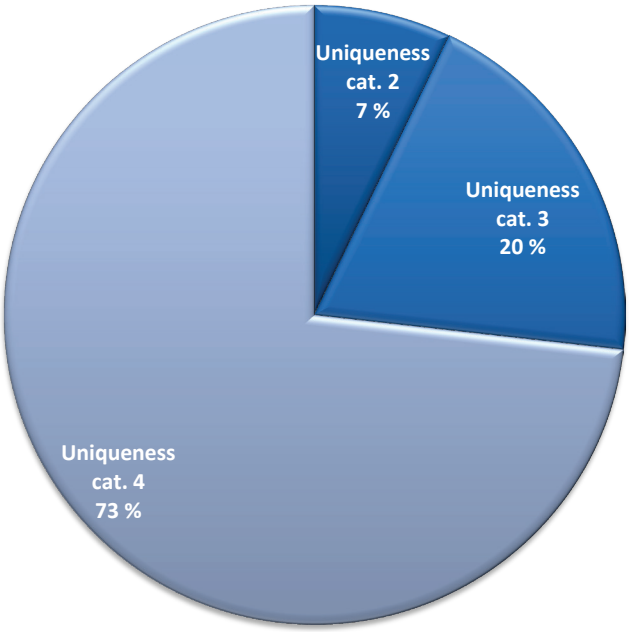


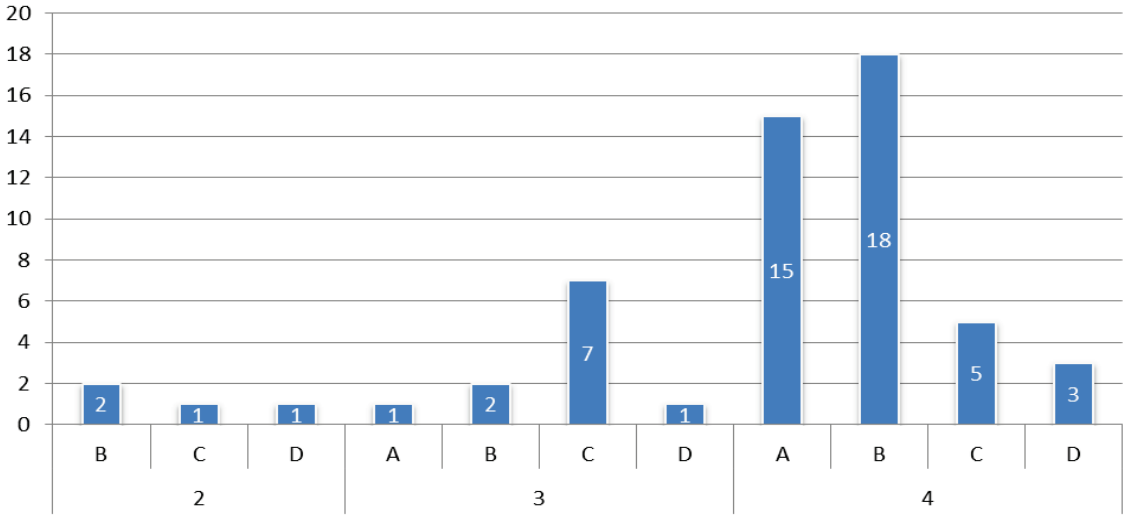
Figure 15 Aggregated picture of object uniqueness in an international context (% indicating part of Objects assessed considered to be in the given uniqueness category)

The assessment in an international context concluded that:

- 41 Objects (73%) were considered to be unique (category 4)
- 11 Objects (20%) were considered rare (category 3)
- 4 Objects (7%) were considered to be limited (category 2).
- None of the assessed objects were considered to be frequent (category 1).

The table below summarizes results presented in the Evaluation of the condition of the Viking Ship Collection (D-02.02)

Transport Category	Potential for Damage	% objects of total in survey	Characteristics of group surveyed
A	Severe	18	-very poor condition -extremely complex to very complex mounts -greater than 2 people to handle/carry Includes Objects which would likely not resist the stresses associated with the preparation for transport. These Objects are very weak and demand very complicated packing techniques.
B	High	31	-very poor to fair condition -very complex to complex mounts -2 or more people required to handle/carry Objects in this category are generally fragile, and have complicated packing requirements, but not as complex as those in Group A. However, potential for damage is high.
C	Moderate	38	-very poor to good condition -complex to less complex mounts -1 or 2 people required to handle/carry These Objects are likely to resist the stresses associated with preparation for transport, but are not as robust as those in class D. There is a risk of some damage occurring during their preparation for transport.
D	Low	13	-fair to very good condition -complex to less complex mounts -1 person required to handle/carry These Objects are relatively robust or require simple packing techniques, resulting in a low potential for damage during their preparation for transport.



Summary Object's Uniqueness (1-Frequent to 4-Unqiue; source, Expert Committee) and Potential for damage (A=Severe to D=Low; source, D-02.02)

The tables below shows scales used in the assessment of the condition and vulnerability of the Objects in the Evaluation of the condition of the Viking Ship Collection (D-02.02) the evaluation is presented in the following table

Condition	Type of mount required
1. very poor	1. extremely complex
2. poor	2. very complex
3. fair	3. complex
4. good	4. less complex
5. very good	

Number to carry	Protection (Transport) Category (Object Profile score)
1. More than two people required to pack and/or carry	A: Severe potential for damage (3-4 points)
2. Two people required to pack and/or carry	B: High potential for damage (5-7 points)
3. One person required to pack and/or carry	C: Moderate potential for damage (8-9 points)
	D: Low potential for damage (10-12 points)

The table below summarizes the assessment of the condition, complexity of moving and uniqueness of the Objects. Uniqueness evaluation is presented as the object's uniqueness in an international and national setting.

Object group	Object	No. items	Type of treatment	Condition[18]	Type of mount required[18]	Number to carry[18]	Object Profile[18] (sum)	Transport Category[18]	Uniqueness assessment by KHM[18]	Uniqueness assessment By NMD[19]
Viking Ships	Oseberg	1	Linseed oil/creosote	3	1	1	5	A	4	4
	Gokstad	1	Linseed oil/ creosote	4	1	1	6	B	4	4
	Tune	1	Linseed oil/ creosote	3	1	1	5	A	3	4
Animal Head Posts:	Carolingian	1	Alum	1	3	3	7	B	4	4
	Barokk hodet	1	Freeze dried	1	3	3	7	B	4	4
	Løvehodet	1	Freeze dried	1	3	3	7	B	4	4
	Akademikeren	1	Freeze dried	1	3	3	7	B	4	4
Sleds	Gustafson's	1	Alum	1	1	1	3	A	4	4
	Schetelig's	1	Alum	1	1	1	3	A	4	4
	4de. slede	1	Alum	1	1	1	3	A	4	4
Sled poles/ slededragene	Sled Pole/skåk 1904.338	1	Dried	3	3	1	7	B	4	4
	1904.337 (7 large pieces)	1	Alum	3	3	1	7	B	4	4
	Den "defekte"	1	Freeze dried	1	3	2	6	B	4	4
	Den "fine"	1	Freeze dried	1	3	2	6	B	4	4
Wagon	Cart	1	Alum						4	4
	1904.250 Hjulv. bak	1	Alum	1	1	1	3	A		
	1904.251 Hjul	1	Alum	1	2	2	5	A		
	1904.257 Dragene	1	Alum	1	2	2	5	A		
	1904. 332 Hjul	1	Alum	2	2	1	5	A		
	1904.333 Hjul	1	Alum	1	2	2	5	A		
Boats	Faering	1	Linseed oil/ creosote	3	2	1	6	B	3	3
	Seksaering	1	Linseed oil/ creosote	3	2	1	6	B	3	3
Other objects	Axe handle/ økseskaft	2	Alum	1	4	2	7	B	1	2
	Baking through/baketrau	1	Alum	1	2	1	4	A	4	4
	Bed (+) – fragment / sengehest (?)	1	Alum	1	2	1	4	A	4	4
	Bowl /øl bolle	1	Alum	2	3	2	7	B	4	4

[18] Assessmen in a national context by Cultural History Museum Staff 2012
[19] Assessment in an international context by experts from National Museum of Denmark 2012

Object group	Object	No. items	Type of treatment	Condition[18]	Type of mount required[18]	Number to carry[18]	Object Profile[18] (sum)	Transport Category[18]	Uniqueness assessment by KHM[18]	Uniqueness assessment By NMD[19]
	Buckets /span	7	Alum (2 dried)	1-4	2-3	1-3	4-10	1A 2B 3C 1D	3	4
	Bucket C55000-156	1	Dried	4	3	3	11	C	4	4
	Bucket C55000-18	1	Dried	2	2	1	5	A	4	4
	Chair	1	Alum	3	2	2	7	B	4	4
	Chests /kister	4	Linseed oil/ creosote + 1 dried	2-4	2-4	2-3	6-11	2B 2C 1D	3	4
	Club / banketre	1	Alum	2	3	3	8	C	3	3
	Cups / Kopper	4	Alum & Dried	2-3	3	3	8-9	C	3	3
	Gokstad Bed posts/ sengestolper	2	Linseed oil/ creosote	3-4	4	2	9-10	1C 1D	3	4
	Hoe / hake	1	Alum	1	3	2	6	B	2	2
	Iron / Strykejern	1	Alum	3	3	3	9	C	4	4
	Ladles / øsekar	5	Alum	2	3	3	8	C	3	3
	Linnen club / linklubbe	2	Alum	2	3	3	8	C	3	3
	Mast tool / buet skipsverktøy	1	Alum	2	3	3	8	C	4	4
	Pitch fork / møkkagreip	1	Alum	1	3	2	6	B	4	4
	Prow / Stavn	2	Alum	2	3	2	7	B	4	4
	Rune stick / runestokk	1	Alum	1	4	3	8	C	2	3
	Saddle / Sadel	1	Alum	2	3	2	7	B	4	4
	Ship tool / Skipsverktøy	1	Alum	3	4	3	10	D	4	4
	Skein-winders / hespetre	2	Alum	1	3	3	7	B	3	4
	Small throughs/små trau	3	Alum	2	3	3	8	C	3	2
	Spades/spader	5	Linseed oil/ creosote	4	4	2	10	D	2	2
	Spoon/sleiv	1	Linseed oil/ creosote	5	4	3	12	D	3	3
	Tent verge board / telt vindski	2	Alum	1	3	2	6	B	3	4
	Wooden figure / figur i tre	1	Alum	3	3	3	9	C	3	3
	Burial chamber Gokstad	1	Linseed oil/ creosote	2	2	1	5	A	3	4
	Gangway Oseberg	1	Linseed oil/ creosote	2	1	1	4	A	3	3
	Large barrels	2	Linseed oil/ creosote	3	3	2	8	C	3	3

APPENDIX 4
RISK ASSESSMENT PRINCIPLES

Risks related to the conditions specific to each of the Scenarios have been identified and assessed based on evaluation of potential hazards in each phase of each Scenario and the likelihood/probability that this may lead to an undesired changes in the Viking Ships and Objects, either during the project (short term) or within the next 100 years after the project (long term).

Damage Risk
=
probability that a hazard will cause an undesired effect
in specified conditions and within a specified time frame and the extent of the damage

The probability that an event will occur has been assessed in two time frames;

- probability of damage during the project phase of a given Scenario (short term)
- probability of damage in the next 100 years after the project (long term)

Individual risks may be specified to only impact part of the assemblage, the probability category still applies.

Table Probability of damage has been assessed using the following scale (Moving process should be understood as the move of the total assemblage)::

Probability category		Description
1	Damage possible	Corresponds to a probability above 10%. An event may occur in one out of ten moving processes.
2	Damage unlikely	Corresponds to a probability between 1% and 10% An event may occur in one out of ten to one out of a hundred moving processes.
3	Damage rare	Corresponds to a probability between An event may occur in one out of a hundred to one out of a thousand moving processes.
4	Damage extremely rare	Corresponds to a probability less than 0.1% in less than one out of a thousand moving processes.

Consequence category		Description	Physical change	Biological change	Chemical change
1	Superficial damage	Repair possible with no or very little effect on the object. Repair not visible or hardly visible. No loss of material. Future stability not likely decreased.	Few hairline cracks. Increased cracquelure, slight change in gloss, small colour changes.	- Infestation requiring cleaning and disinfectant - Corrosive (e.g. acidic) deposits on object (excrement from birds/ bats/ mice etc.) - Introduction of vermin/ organic liquids as a result of nesting	Minor surface alterations. No structural (e.g. cellular) alterations to the mass of the object Tarnishing
2	Minor damage	Object can be repaired without significant effects on the object. Repair may be visible, but not extensive. No or very little loss of material expected. Future stability slightly decreased.	Patchy colour changes, Delamination Loosening of joints	Biological growth on the surface leading to staining of surface (e.g. mould/ microorganisms)	Alteration to the surface structure and/or minor structural alterations to the mass of the object.
3	Significant damage	Damage where repair is possible, but not without significant influence on the object. Some loss of material may typically also occur. Very likely to decrease future stability of the object.	- Deformation of the structure - Defacement of the surface (loss of tool marks). - Uneven swelling and shrinkage. - Embrittlement - Fracturing (into larger pieces) - Desiccation – drying out	Extensive infestation (gnawing / scratching object surface). Extensive biological growth on the surface leading to widespread staining of surface (e.g. mould/ microorganisms)	Disfigurement of the surface structure and/or major structural alterations to the mass of the object.
4	Extensive damage/total loss	Object is not possible to repair and/or significant loss of material due to disintegration of wood or other material. Severely decreases future stability of object.	Deformation of the structure (loss of object shape, e.g. irreversible bending or twisting of structural members, excessive pressure, cellular breakdown of wool) Defacement of the surface (total loss of surface detail, patterns/carving/ features are no longer recognisable) Crushing (into fragments)	Disintegration - reducing to powder (e.g. due to wood-boring insects). Extensive biological growth on the surface leading to loss of surface detail (e.g. mould/ / microorganisms)	Structural breakdown Total loss of surface detail (spalling, powdering, flaking) New pollutants or unexpected chemical reaction in existing material leading to efflorescence (e.g. salt efflorescence)

The combination of the probability scale and the consequence scale gives the following risk assessment matrix.

Numbers in the cells indicate the weighted risk level for the given combination of probability and consequence and are used in aggregation of the risk picture. The weight is intended for the purpose of comparing risk levels and is not an actual calculated value.

Probability	1 Superficial damage	2 Minor damage	3 Significant damage	4 Extensive damage/ total loss
D Damage possible	7	11	14	16
C Damage unlikely	4	8	12	15
B Damage rare	2	5	9	13
A Damage extremely rare	1	3	6	10

Consequence

Risk level:	1 Insignificant	2 Significant	3 Critical

Probable impact on values = Combination of the damage risk to the Objects and the uniqueness of the Object affected by the risk

Total risk thus consists of:

- Probability of an undesired event
- Potential damage from the event
- Uniqueness of the Object impacted by the event

Acceptance criteria are based on a combination of risk level (vertical axis) and uniqueness (horizontal axis):

	1 Frequent	2 Limited	3 Rare	4 Unique
3 Critical				
2 Significant				
1 Insignificant				

Risk level / Uniqueness

Effect classification:	1 Acceptable	2 To be avoided	3 Unacceptable
	Acceptable, process does not require additional actions to be undertaken	Should be avoided, all possible precautions shall be investigated before the process is undertaken	Unacceptable, the process must be redesigned to mitigate risk or be abandoned

APPENDIX 5
RISK ASSESSMENT TABLE

The Risk Assessment Table is established by combining the principles from the Canadian Conservation Institute (CCI)[20] risk assessment methodology with the scenario process description. The potential causes, consequences and mitigating actions have been established based on discussions in the Expert Committee and with the Viking Ship Museum staff. It is not intended as a complete list of potential causes, but gives an indication of the potential risk areas and provides a basis for the discussion on most relevant risks to be evaluated. The risk picture presented in Appendix 6 and 7 is established based on the Risk Assessment Table.

[20] Canadian Conservation Institute Website: http://www.cci-icc.gc.ca/

Risk Assessment matrix (consequence & causes related to each phase)

Hazards	Project phase	Potential Consequences	Preparing the collection (packing)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
	Phase Description	*General consequences related to the Hazards/agents of deterioration*	*Main goal is to protect objects from potential Hazards in the following processes. This includes improved support to the structures and wrapping/packing the objects*	*Mounting the objects into stable frames has been proposed to improve balance of weight distribution and to avoid torsion. The frame should also enable mounting onto vibration absorbing device*	*In order to move the large objects (e.g.Viking ships), openings have to be made in the walls of the existing building. It is presumed that all other objects are moved before the walls are opened, leaving only the largest objects inside the building. In scenario 3 the existing building needs to be refurbished.*	*All objects are moved onto transportation device inside the stable frames. Smooth surface and no tilting of the objects during the movement is presumed. Ships will have to be lifted out of openings made several meters above the ground and lowered on to transport device.*	*All objects will be transported inside stable frames. Vibration absorbing structure and no tilting of the objects during the movement is presumed. Objects are lifted from transportation device and moved into their new location.*	*Protective packing including stable frame is removed from the object. Temporary supporting structures are replaced with long term support structures to be used while objects are on display. Objects are inspected for potential change.*	*Objects are on display in new/refurbished museum. They are exposed gravity and the radiation, pollution, temperature and humidity of their new location. Research into conservation, history and craftsmanship continues.*
Direct Physical Forces	***Agents of Deterioration***								
	Shock, vibration, abrasion, and gravity Cumulative (improper handling or support) Catastrophic (e.g., earthquake, war, floor collapse, improper handling): - break, distort, puncture, dent, scratch, and/or abrade all types of artifacts	•Part of object break and fall off •Dent, scratch or abrasion on object surface •Indicators of handcraft lost •Object collapse due to structural failure •Tensions created between new and original material in object give long term degradation of stability	•Inadequate competence from packing personnel •Wrong use of materials in packing (too soft/too firm) •Packing materials not adequately tailored to object surface •Use of wrong materials •Support structure unable to distribute load •Excessive load from packing materials •Failure/Damage to support structure	•Excessive tilting of object •Wrong handling by personnel during mounting/assembly •Excessive local pressure during lifting (person or support structure) •Torsion/twisting of object o Wrong frame assembly or design o Unbalanced lifting	•Impact to items in museum collection from falling objects •Vibrations from heavy cutting machinery when tearing down wall for relocation of large objecte (e.g. viking ships).	•Vibrations from movement over uneven surface •Excessive tilting of object when exiting building or loading onto transport unit •Support structure is damaged or shifts failing to distribute load adequately •Uneven surface causes torsion from support structure	•Vibrations from movement over uneven surface •Excessive tilting of object due to inclinations on transport route •Impact from collision with foreign object (car/bike/other) •Inadequate clearing between transport frame and surrounding structures on transport route cause collision o Foreign object falls on museum item •Inadequate protection from interested spectators wanting to touch objects	•Inadequate competence from unpacking personnel •Wrong distribution of load when support structure is removed •Part of support structure falls on item during dismantling (wrong dismantling sequence / undiscovered damage from previous phase •Vibrations from heavy machinery when Finalizing building after objects are installed •Impact from falling objects when Finalizing building after objects are installed	•Museum visitors touch objects on display •Object on display is dropped during cleaning •Excessive physical force is applied when cleaning object on display •Vibrations from external infrastructure (road/railway) •Inappropriate transportation route from display to research area (distance/ inclination/ uneven surface)
	Proposed risk reducing actions		Avoid: •Train staff in techniques of handling artifacts. •Plan movements of artifacts. •Avoid unreliable art handlers. Block: •Block forces from all sides using adequate size and number of packing cases, proper foam to absorb shock and vibration, and braces or restraints for vibration-prone components. •Train staff in techniques of supporting and packing artifacts. •Keep artifacts separated from each other. Detect: •Format condition reports compatible with museum catalog. •Record new damage. Take good photos.	Avoid: •Avoid handles at incorrect heights. •Provide lifts and dollies to move artifacts safely. •Ensure smooth surfaces; smooth ramps; and slow, smooth lifts. Block: •Allow adequate space for loading. Install impact-absorbing perimeter around doors (e.g., rubber surround). • Detect: •Detect forces by using tipping indicators, shock detectors, and data loggers.	Block: •Block forces from all sides using adequate size and number of packing cases, proper foam to absorb shock and vibration, and braces or restraints for vibration-prone components. Detect: •Detect forces by using tipping indicators, shock detectors, and data loggers	Avoid: •Provide lifts and dollies to move artifacts safely. •Ensure smooth surfaces; smooth ramps; and slow, smooth lifts. Block: •Allow adequate space for loading. Install impact-absorbing perimeter around doors (e.g., rubber surround). •Block forces from all sides using adequate size and number of packing cases, proper foam to absorb shock and vibration, and braces or restraints for vibration-prone components. Detect: •Detect forces by using tipping indicators, shock detectors, and data loggers	Avoid: •Transport artifacts in well-maintained air-ride trucks. Block: • Detect: •Detect forces by using tipping indicators, shock detectors, and data loggers	Block: •Allow adequate space for unloading. •Install impact-absorbing perimeter around doors (e.g., rubber surround). Detect: •Detect forces by using tipping indicators, shock detectors, and data loggers Recover/Treat: •Provide conservation laboratory equipment to treat damaged artifacts	Avoid: •Avoid areas of high seismic activity. Avoid building on soft, loose soils. Ensure adequate floor strength, smooth and soft interior wall finish, and adequate access. •Avoid unstable shelves and cabinets. Immobilize and secure artifacts Block: •Separate artifacts from each other and from the public. •Provide discrete cradles and supports made of inert padding. Detect: •Leave adequate space to allow for inspection of artifacts. Recover/Treat: •Provide conservation laboratory equipment to treat damaged artifacts

Risk Assessment matrix (consequence & causes related to each phase)

Hazards	Project phase	Potential Consequences	Preparing the collection (packing)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
Thieves, Vandals Displacers	Intentional (criminals): steal small or portable artifacts. disfigure valuable, popular, or symbolic artifacts. Unintentional (staff, users): lose or misplace any type of artifact	•Same potential consequences as for Direct Physical Forces •Item is lost •Item is disfigured	•Small items or parts of items are lost during packing	•Thieves or vandals take advantage of the project to gain access to museum artefacts	•Security guards not appropriately stationed to detect intruders during •Lack of surveillance cameras in the buildings	•Lack of security arrangements during transportation leave objects available for thieves and vandals	•Lack of security arrangements during transportation leave objects available for thieves and vandals	•Small items or parts of items are lost during unpacking •Lack of security arrangements during unpacking and finalization of building after relocation leave objects available for thieves and vandals	•Lack of security arrangements in museum perimeters leave objects vulnerable for thieves and vandals •Lack of protection between visitors and objects on display •Small items or parts of items are lost during cleaning Avoid: •Implement a security program appropriate to the value of the collection. •Integrate security program with museum services and with municipal security services. Block: •Block entry with strong/barred windows and strong walls. •Provide secure walls, ceilings, and doors. •Maintain access and perimeter security systems. •Keep doors and windows locked. Control the circulation of keys. •Secure display cases and shelves. Provide separate access to light box. Detect: •Station personnel in public areas. •Maintain a catalog to identify losses. •Routinely inspect collections and building. •Use proximity detectors, etc. to warn visitors crossing thresholds Respond: •Train staff in appropriate response to intruders. •Inform local police department of museum layout and of location of valuable artifacts. Recover/Treat: •Recover lost artifacts. •Treat vandalized artifacts
		Proposed risk reducing actions	Respond: •Train staff in appropriate response to intruders. •Inform local police department of museum layout and of location of valuable artifacts. •Reconsider all stages.	Block: •Block entry with controlled access system and with adequate locks on cabinets that hold valuable items. •Patrol areas to deter intruders or displacers. Detect: •Detect intruders by ensuring clear sight lines and appropriate lighting. Respond: •Provide offices and security posts for security staff	Block: •Block entry with controlled access system and with adequate locks on cabinets that hold valuable items. •Block access during construction by having an an open perimeter, no hidden entrances •Patrol areas to deter intruders or displacers. Detect: •Detect intruders by ensuring clear sight lines and appropriate lighting. Respond: •Provide offices and security posts for security staff	Avoid: •Avoid prominent labelling of packing cases Block: •Block entry by enclosing and securing loading bay. •Hire secure, reputable carriers. Detect: •Establish security post to detect intruders or displacers. •Detect intruders and displacers by using electronic detectors.	Avoid: •Avoid prominent labelling of packing cases. Block: •Use strong packing cases (locks optional). •Hire secure, reputable carriers. Detect: •Detect intruders and displacers by using electronic detectors. Respond: •Provide communicators and equipment for security personnel.	Block: •Block entry with controlled access system and with adequate locks on cabinets that hold valuable items. •Patrol areas to deter intruders or displacers. Detect: •Detect intruders by ensuring clear sight lines and appropriate lighting. Respond: •Provide offices and security posts for security staff	

Risk Assessment matrix (consequence & causes related to each phase)

Hazards	Project phase	Potential Consequences	Preparing the collection (packing)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
Fire	destroys, scorches, or deposits smoke on all types of artifacts, particularly those that contain organic materials	•Scorching artefacts made of fabric and wood •Deposit smoke on artefact(s) •Destroy structure	•Flammable packing material placed too close to warm objects (e.g. oven/heater) •Chemical liquids or solvents (e.g. glue) used in packing material self-ignite •Smoking •Wrong wiring in electrical appliances	•	•Friction or sparks from cutters or welding equipment used when dismantling building structure (e.g. for moving Viking ships) ignite flammable packing material or other flammable objects •Wrong wiring in electrical appliances	•Smoking	•Friction during transport cause fire •Wrong electrical wiring in transportation rig	•Flammable packing material placed too close to warm objects (e.g oven/heater) •Friction or sparks from (e.g. welding) equipment used when finalizing building structure ignite packing material or other flammable objects •Wrong wiring in electrical appliances	•Flammable material placed too close to warm objects (e.g oven/heater) •Wrong wiring in electrical appliances
	Proposed risk reducing actions		Avoid: •Implement a fire safety program in consultation with local authorities (see NFPA publications). Train staff in fire prevention techniques. Block: •Maintain fire barriers and fire separations. Keep fire doors closed. •Limit chaos and debris during packing. •Block fire with closed fire-resistant portable cabinets Detect: •Detect fire by using smoke and heat detectors connected to a central annunciator panel •Establish whom to call in case of fire alarm. Test fire detection systems as required. Respond: •Place enough portable fire extinguishers of adequate size and capacity near exits. •Consult fire authorities for details. •Activate fire disaster plan. Inform authorities of museum layout and of location of valuable or flammable artifacts. Train staff in use of fire extinguishers. Reconsider all stages. Recover/Treat:	Block: •Maintain fire barriers and fire separations. Keep fire doors closed. Limit chaos and debris during packing •Leave adequate space (1.5 m) between walls and objects to block spread of fire.	Block •Block fire with closed fire-resistant cabinets •Block spread of fire with fire-resistant structural elements, compartments, and fire separations. •Use smoke-control systems. •Leave adequate space (1.5 m) between walls and objects to block spread of fire. Detect: •Detect fire by using smoke and heat detectors connected to a central annunciator panel. • Respond: •Place enough portable fire extinguishers of adequate size and capacity near work areas. •Use fire suppression systems in areas with remaining objects.	Respond: •Use fire suppression systems in loading bay that are designed for fires involving vehicles and shipping materials.	Block: •Block fire with smoke-tight, fire-resistant packing cases.	•	Avoid: •Use only approved and well-ventilated lights, audio-visual equipment, motors, etc. Block: •Block fire with smoke-tight, fire-resistant display cases. Detect: •Detect fire by using smoke and heat detectors connected to a central annunciator panel. Respond: •Place enough portable fire extinguishers of adequate size and capacity near exits. Consult fire authorities for details. Recover/treat: •Provide conservation laboratory equipment to treat damaged artifacts

Risk Assessment matrix (consequence & causes related to each phase)

Hazards	Project phase	Potential Consequences	Preparing the collection (packing) (Relevant in scenario 1,2)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
Water	causes efflorescence or tide marks in porous materials. swells organic materials. corrodes metals. dissolves some materials (e.g., glue). delaminates, tents, and/or buckles layered components of an artifact. loosens, fractures, or corrodes joined components of an artifact. shrinks tightly woven textiles or canvases	•Corrode nails and screws used in restoration of objects •Dissolve fabric (e.g ropes, cloth) •Corrosion on metal objects •Uneven swelling and/or buckling on original parts and parts added during restoration leads to structural failure •Swelling, tenting and/or buckling of wooden objects	•Moisture/water from packing material is spilled on object	•	•Damage from work on the building structure cause leakage •Damage to plumbing lead to flooding or water spray •Damage or failure to fire sprinkler system	•Lack of protection against rain when moving objects out of building •Large variations in temperature cause condensation on objects inside package when moving out of the building	•Damage to protection against rain during transport •High RH cause condensation on objects during transportation	•Lack of protection against rain when moving objects into building •Large variations in temperature cause condensation on objects when moving into new building •Water deposited on packing leaks on to objects during unpacking	•Damage to building structure cause water leakage •Damage to plumbing •Damage or failure to fire sprinkler system •Unintentional engagement of sprinkler system
		Proposed risk reducing actions	Block: •Block water by placing the wrapped object inside a water-resistant packing case. •Design drain channels on the packing case lid to prevent water accumulation.	Block: •Block water by placing the wrapped object inside a water-resistant packing case. •Design drain channels on the packing case lid to prevent water accumulation.	Avoid: •Keep all artifacts off the floor and away from walls and water sources Detect: •Detect water by using water detectors connected to a central annunciator panel. Block: •Maintain barriers to water (e.g., watersheds on display cases). Protect artifacts with temporary waterproof covers if leaks are anticipated. Respond: •Stock clean-up equipment (e.g., pumps, mops, wet vacuum cleaner). Recover/Treat: •Provide fans, drying racks, and other equipment to treat damaged artifacts	Avoid: •Avoid packing cases that are not supported by skids or feet. •Avoid locating loading bay area below grade. Block: •Have roof over loading bay •Ensure adequate drains in loading bay.	Avoid: •Avoid placing packed objects within 10 cm of the floor. Block: •Design drain channels on the packing case lid to prevent water accumulation. Detect: •Detect water by using water detectors connected to a central annunciator panel.	Avoid: •Avoid locating loading bay area below grade. Block: •Have roof over loading bay •Ensure adequate drains in loading bay. Detect: •Inspect collections for water Respond: •Stock clean-up equipment (e.g., pumps, mops, wet vacuum cleaner). Recover/Treat: •Provide fans, drying racks, and other equipment to treat damaged artifacts.	Avoid: •Inspect and maintain sprinkler system, roof, and plumbing. •Keep all artifacts off the floor and away from walls and water sources (e.g., air conditioning units). Inform cleaners of risks. Block: •Maintain barriers to water (e.g., watersheds on display cases). Protect artifacts with temporary waterproof covers if leaks are anticipated. Detect: •Inspect collections for water, especially after heavy rain or periods of thaw. Respond: •Activate flood disaster plan. Label and maintain cut-off valves. •Store emergency supplies. Reconsider all stages. Recover/Treat: •Establish emergency treatments for wet artifacts: dry, freeze, or keep wet. Treat artifacts damaged by water

Risk Assessment matrix (consequence & causes related to each phase)

Hazards	Project phase	Potential Consequences	Preparing the collection (packing)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
Pests	Insects: consume, perforate, cut, graze, tunnel, and/or excrete, which destroys, weakens, disfigures, or etches materials, especially furs, feathers, skins, insect collections, textiles, paper, and wood. Vermin, birds, and other animals: gnaw organic materials and displace smaller items. foul artifacts with faeces and urine. gnaw through or foul inorganic materials if they present an obstacle to reaching the organic material. Mould and microbes (see also "Incorrect Relative Humidity, Damp"): weaken or stain organic and inorganic materials	•Wooden materials are perforated causing structural weakness or failure •Parts of fabrics are consumed •Stains on fabrics	•Pests from materials in transportation equipment are transferred to objects	•Pests from materials used in transportation equipment are transferred to objects	•Mice or other pests enters the building through openings made in order to move the objects	•Pests gain access when objects are moved out of building	•Pests gain access to objects during transportation	•Pests gain access to building during construction •Pests gain access when building is opened to receive the objects	•Lack of pest control
	Proposed risk reducing actions		Avoid: •Avoid infested packing cases and packing materials. Block: •Block pests with sealed, insect-resistant, vermin-resistant packing cases. Bag artifacts. Detect: •Provide easy access for complete inspection (e.g., underneath and behind transport areas).	Detect: •Provide easy access for complete inspection (e.g., underneath and behind transport areas).	Avoid: •Avoid creating pest habitats inside and outside the building. •Contain and isolate food and garbage areas. •Use non-attractant lighting. •Use elevated cabinets to eliminate crevices and to ensure that the entire floor can be cleaned. Block: •Block pests by using well-sealed, insect-resistant storage cabinets and containers. Detect: •Provide easy access between cabinets and between artifacts for complete inspection (e.g., underneath and behind transport areas).. Use appropriate traps. Respond: •Design cases and shelves for easy cleaning.	Avoid: •Avoid garbage in loading bay. Provide an exterior site for garbage. Block: •Block pests by using well-sealed, insect-resistant storage cabinets and containers. •Pay attention to seal details around loading bay door and interior access doors. •Have loading area on separate HVAC zone. Detect: •Provide an adequate quarantine room close to loading bay.	Block: •Block pests by using well-sealed, insect-resistant storage cabinets and containers. •Maintain all seals, especially at ground level.	Avoid: •Avoid garbage in loading bay. Provide an exterior site for garbage. Block: •Pay attention to seal details around loading bay door and interior access doors. Have loading area on separate HVAC zone. •Quarantine and examine incoming artifacts, building materials, and packing cases. •Perhaps apply perimeter pesticides Detect: •Quarantine and examine incoming artifacts, building materials, and packing cases. •Provide an adequate quarantine room close to loading bay. Recover/Treat: •Provide conservation laboratory equipment to treat damaged artifacts •Treat artifacts damaged by pests	Avoid: •Avoid using infested materials for display cases. Avoid wool carpets in exhibit halls. •Establish an integrated pest management (IPM) program suitable to the building and to the type of collection. •Keep collections neat, clean, and free of foodstuffs. Block: •Use mineral and metal building fabric. •Pay attention to seal details. •Establish separate HVAC zones for eating areas and workshops. •Maintain sanitary perimeters. •Block pests by using well-sealed, insect-resistant, vermin-resistant display cases and cabinets. •Maintain all seals, especially at ground level. •Perhaps apply perimeter pesticides Detect: •Inspect collection and traps regularly. Identify pests and maintain a log. Respond: •Respond to infestation based on IPM principles. Remove and quarantine infested artifacts on display or in storage. Consider health risks. Reconsider all stages. Recover/Treat: •Treat artifacts damaged by pests

Risk Assessment matrix (consequence & causes related to each phase)

Hazards	Project phase	Potential Consequences	Preparing the collection (packing) (Relevant in scenario 1,2)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
Contamination	Indoor and outdoor gases (e.g., pollution, oxygen) / Liquids (e.g., plasticizer, grease) / Solids (e.g., dust, salt): disintegrate, discolour, or corrode all artefacts, especially reactive or porous materials.	•Polluted dust from traffic react with surface of objects •Gases cause discolouration •Salt deposited on object cause corrosion	•Packing material contain contaminating substances (evaporating gasses) •Contaminating substances used in packing material is deposited on object	•Grease and/or oil from transportation frame is deposited on object by mistake	•Dust from dismantling of building structure is deposited on objects	•Grease and/or oil from transportation frame leaks on to object •Dust and pollen from the outside air is deposited on objects and packing material	•Grease and/or oil from transportation frame leaks on to object •Dust and pollen is whirled up from the road and is deposited on objects and packing material	•Dust and pollen deposited on packing material is transferred to objects during unpacking •Fumes and gasses from new building materials	•Lack of filtering in ventilation cause pollen and dust to deposit on objects •Dust from visitors •Fumes and gasses from material used in presentation cases
		Proposed risk reducing actions	Avoid: •Identify susceptible artifacts. •Establish a list of display materials. •Use only clean, non-dusting packing case materials that are approved for museum use. •Test unknown materials. •Train staff to use appropriate gloves. Block: •Block contaminants by using airtight cases and barrier coatings. •Block contaminants by using inert, clean wrapping materials. Respond: •Place absorbants in packing cases	Avoid: •Train staff to use appropriate gloves. •Use only clean, non-dusting packing case materials that are approved for museum use. Block: • Block contaminants by using inert, clean wrapping materials.	Detect: •Detect contaminants by using gas dosimeters. Respond: •Maintain any filters and absorbers. •Maintain cleanliness. •Remove artifacts from problem areas. Ventilate. Reconsider all stages.	Block: •Block contaminants with an adequate extraction system for vehicle exhaust. Detect: •Detect contaminants by using gas dosimeters. •	Detect: •Detect contaminants by using gas dosimeters. •	Avoid: •Train staff to use appropriate gloves. Block: •Measure enclosure leakages, and seal if necessary. Detect: •Check for dust, changes in colour/patina, tarnish, fingerprints, and loss of strength. •Use gas dosimeters. Recover/Treat: •Treat artifacts damaged by contaminants	Avoid: •Identify susceptible artifacts. Establish a list of suitable building and display materials. •Test unknown materials. •Train staff to use appropriate gloves. •Avoid locations with high pollution or dust and with high local emissions (e.g., roadways). •Avoid building materials that are sources of contaminants. Block: •Block external contaminants with an airtight building. •Have separate ventilation to smoking areas and parking facilities. Filter fresh air intake. •Measure enclosure leakages, and seal if necessary. Respond: •Recirculate and filter air. •Maintain any filters and absorbers. •Maintain cleanliness. •Remove artifacts from problem areas. Ventilate. Reconsider all stages. Recover/Treat: Treat artifacts damaged by contaminants

Risk Assessment matrix (consequence & causes related to each phase)

Agents	Project phase	Potential Consequences	Preparing the collection (packing)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
Radiation	Ultraviolet: disintegrates, fades, darkens, and/or yellows the outer layer of organic materials and some coloured inorganic materials. Unnecessary light: fades or darkens the outer opaque layer of paints and wood to a typical depth of 10 µm to 100 µm, or to greater depths on more transparent layers	•Fading or darkening outer layer of wood •Fading structures on fabrics	•Exposure to ultraviolet light when moved out of presentation cases for packing •Lack of UV protection in packing materials used	•Uneven exposure to ultraviolet light due to variations in protective packing	•Lack of UV protection in packing materials lead to exposure to direct or indirect sunlight when opening building structure	•Lack of UV protection in packing materials expose objects to sunlight when moved out of building into transportation vehicle. (Transparent or light coloured packing material)	•Lack of UV protection in packing materials exposes object to sunlight during transportation (Transparent or light coloured packing material)	•Lack of UV protection in packing materials exposes object to sunlight when moved into new building (Transparent or light coloured packing material)	•Lack of protection from windows or display case exposes objects to direct or indirect sunlight when on display Avoid: •Establish optimum light levels, UV levels, and light sources. •Estimate fading rates of various artifacts, and then establish exposure times and schedules. Block: •Close curtains, blinds, shutters, etc. when the museum is closed. •Cover cases and turn off lights when no viewers are present. •Block radiation with UV filters on windows. •Use small windows, solar screens, louvres, etc. •Separate bright public access areas from display areas, and provide adaptation paths between the two. Detect: •Detect radiation by using UV meters, light meters, and light dosimeters.Detect: •Measure new installations for UV and light levels. •Monitor any light dosimeters. Respond: •Reconsider all stages. Recover/Treat: •Treat artifacts damaged by light and UV, where possible
		Proposed risk reducing actions	Avoid: •Avoid unnecessary light on artifacts. Use timers and multi-level lighting. •Avoid general lighting; use task lighting instead. Avoid high sources of UV. Block: •Block radiation by using opaque packaging. •Block UV radiation by placing UV filters on lamps. If possible, place UV filters on glazing. Use curtains, shutters, and blinds. Detect: •Detect radiation by using UV meters, light meters, and light dosimeters.	Avoid: •Avoid general lighting; use task lighting instead. Avoid high sources of UV. Block: •Block radiation by using opaque packaging. Detect: •Detect radiation by using UV meters, light meters, and light dosimeters.	Avoid: •Avoid unnecessary light on artifacts. Use timers and multi-level lighting. Block: •Block radiation by using opaque packaging. • Detect: •Detect radiation by using UV meters, light meters, and light dosimeters.	Avoid: •Avoid unnecessary light on artifacts. Block: •Block radiation by using opaque packaging. • Detect: •Detect radiation by using UV meters, light meters, and light dosimeters.	Avoid: •Avoid unnecessary light on artifacts. Detect: •Detect radiation by using UV meters, light meters, and light dosimeters.	Avoid: •Avoid windows. Establish area lighting that can be switched on over specific locations Detect: •Detect radiation by using UV meters, light meters, and light dosimeters. Recover/Treat: •Treat artifacts damaged by light and UV, where possible •	

Risk Assessment matrix (consequence & causes related to each phase)

Hazards	Project phase	Potential Consequences	Preparing the collection (packing)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
Incorrect Temperature	Too high: causes gradual disintegration or discolouration of organic materials, especially if they are chemically unstable (e.g., acidic paper, colour photographs, nitrate and acetate films). NOTE: Most materials decompose gradually at room temperature, but the time scale for complete destruction is in millennia. Too low: causes embrittlement, which results in fractures of paints and of other polymers. Fluctuations: cause fractures and delamination in brittle, solid materials, especially if they are layered. cause RH fluctuations (see "Incorrect Relative Humidity").	•Embrittlement and fractures in wooden objects	•Exposed to fluctuating temperature in building at Bygdøy when moved out of presentation cases for packing and transport •Packaging unable to ensure stable temperature	•Exposed to fluctuating temperature in building at Bygdøy when moved out of presentation cases for packing and transport	•Exposed to fluctuation in temperature when building is opened up to move packaged objects out of the building •	•Exposure to sunlight causing rapid increase in temperature (can be accelerated by dark coloured packing material) •Exposure to sunlight causing high temperature during transport (can be accelerated by dark coloured packing material) •Exposed to fluctuation in temperature when moved out of the museum building	•Exposure to sunlight causing high temperature during transport (can be accelerated by dark coloured packing material)	•Exposed to rapid change in temperature when moved into new museum building	•Long term fluctuation in temperature in the new museum building – fluctuations in new building will not be identical to today's situation
		Proposed risk reducing actions	Block: •Block incorrect temperature by using insulated packing cases. Detect: •Place an electronic data logger, and a thermometer with external readout, in packing case.	Block: •Block incorrect temperature by using insulated packing cases. Detect: •Place an electronic data logger, and a thermometer with external readout, in packing case.	Avoid: •Avoid locating transport cabinets near heat sources (e.g., radiators, heaters). Block: •Block incorrect temperature by using insulated packing cases. Detect: •Use thermohygrographs, thermometers, data loggers, temperature monitors, and alarms.	Avoid: •Enclose loading bay, if possible Block: •Block incorrect temperature from spreading to other areas by providing a separate HVAC zone for loading area. Detect: •Place an electronic data logger, and a thermometer with external readout, in packing case.	Avoid: •Avoid vehicles that are not temperature controlled. Block: •Block incorrect temperature by using insulated packing cases. Detect: •Place an electronic data logger, and a thermometer with external readout, in packing case.	Avoid: •Enclose loading bay, if possible Block: •Block incorrect temperature from spreading to other areas by providing a separate HVAC zone for loading area. Recover/Treat: •Treat artifacts damaged by incorrect temperature	Avoid: •Define the correct temperatures for various artifacts. Block: •Maintain insulation. Ensure adequate distance between artifacts and hot or cold surfaces. Detect: •Monitor measuring instruments and interpret the data. Respond: •Plan response to HVAC system failures. •Reconsider all stages. Recover/Treat: •Treat artifacts damaged by incorrect temperature

Risk Assessment matrix (consequence & causes related to each phase)

Hazards	Project phase	Potential Consequences	Preparing the collection (packing)	Loading objects onto stable frames (Relevant in scenario 1,2)	preparing existing building for the project (Relevant in scenario 1,2,3)	Loading objects for transport (Relevant in scenario 1,2)	Transport from present to new location (Relevant in scenario 1,2)	Unpacking objects (Relevant in scenario 1,2,3)	Research & Dissemination (Relevant in scenario 1,2,3)
Incorrect Relative Humidity (RH)	Damp (over 75% RH): causes moulds (which stain and weaken organic and inorganic materials), corrosion (of metals), and shrinkage (of tightly woven textiles). RH above or below a critical value: hydrates/dehydrates some minerals and corrodes metals that contain salts. RH above 0%: gradually disintegrates and discolours organic materials, especially materials that are chemically unstable (e.g., acidic paper). Fluctuations: shrink and swell unconstrained organic materials. crush or fracture constrained organic materials. cause layered organic materials to delaminate, tent, and/or buckle.loosen joints in organic components.	•Uneven swelling due to RH fluctuations lead to structural failure in areas with original and new material (may lead to complete structural failure) •Embrittlement or fractures in alum conserved objects due to drop in humidity leading to loss of physical stability (worst case parts or entire items disintegrate) •(re)activation of corrosion (metal) •	•Exposed to changing humidity in building at Bygdøy when moved out of presentation cases for packing and transport •Packaging unable to ensure correct Relative Humidity	•Lack of containment in temporary protection exposes object to changing humidity in building at Bygdøy while being mounted onto frame	•Lack of containment in temporary protection exposes object to fluctuation in humidity when building is opened up to allow moving of packaged objects out of the building	•Lack of containment in temporary protection exposes object to rapid change in humidity when moved out of the museum building	•Lack of containment in temporary protection exposes object to fluctuation in humidity during transportation	•Lack of containment in temporary protection exposes object to rapid change in humidity when moved into new museum building	•Long term fluctuations in humidity in the new museum building – fluctuations in new building will not be identical to today's situation
		Proposed risk reducing actions	Avoid: •Avoid temporarily locating artifacts near sources of incorrect temperature and humidity (e.g., lamps, damp floors, exterior walls). Block: •Block incorrect RH by wrapping artifacts and by using airtight packing cases. Detect: •Place an electronic data logger, or a hygrometer with external readout, in packing case.	Avoid: •Avoid temporarily locating artifacts near sources of incorrect temperature and humidity (e.g., lamps, damp floors, exterior walls). Block: •Block incorrect RH by wrapping artifacts and by using airtight packing cases. Detect: •Place an electronic data logger, or a hygrometer with external readout, in packing case.	Avoid: •Avoid temporarily locating artifacts near sources of incorrect temperature and humidity (e.g., lamps, damp floors, exterior walls). Block: •Maintain vapour barriers. Ensure adequate distance between artifacts and cold surfaces. •Measure enclosure leakages, and seal if necessary. Detect: •Place an electronic data logger, or a hygrometer with external readout, in packing case.	Avoid: •RH control is provided by packing case. Block: •Block incorrect RH with an independent HVAC zone for loading area.	Avoid: •Avoid vehicles that are not humidity controlled. Block: •Block incorrect RH by wrapping artifacts and by using airtight packing cases. Detect: •Place an electronic data logger, or a hygrometer with external readout, in packing case. Respond: •Use buffers such as silica gel, wood, cotton, and paper, if required.	Avoid: •RH control is provided by packing case. •Allow time for packing cases to reach room temperature before opening. Block: •Maintain vapour barriers. Ensure adequate distance between artifacts and cold surfaces. •Measure enclosure leakages, and seal if necessary. •Block incorrect RH with an independent HVAC zone for loading area. Detect: •Monitor measuring instruments and interpret the data. Recover/Treat: •Treat artifacts damaged by incorrect RH.	Avoid: •Define the correct RH range for various artifacts, and inform relevant staff. •Allow time for packing cases to reach room temperature before opening. Block: •Maintain vapour barriers. Ensure adequate distance between artifacts and cold surfaces. •Measure enclosure leakages, and seal if necessary. Detect: •Monitor measuring instruments and interpret the data. Respond: •Plan response to HVAC system failures. Maintain buffers in cases. •Reconsider all stages. Recover/Treat: •Treat artifacts damaged by incorrect RH.

APPENDIX 6
OVERVIEW OF MAJOR EVENTS WITH RELATED MITIGATING ACTIONS, CONTROLS AND BARRIERS

The following pages illustrates potential major events that may lead to significant physical, biological or chemical change to the Objects in the Viking Ship Assemblage. The major events have been identified based on the Risk Assessment Matrix presented in Appendix 5. An overview of the evaluation of each risk is presented in Appendix 7.

Based on the risk assessment process, nine top events were identified, see table below. The identified risks were linked to the relevant top events, establishing a basis for the discussion on risk-reducing measures for each Scenario. This is used to build the basis for the recommendations on practical measures needed in order to implement the recommended Scenario with a minimal level of risk.

Hazard	Name
Direct physical forces	Major structural deformation and/or loss of material on alum preserved Objects
Direct physical forces	Major structural deformation and/or loss of material on Viking Ships
Thieves, Vandals, Displacers	Objects are stolen, vandalized or misplaced
Fire	Fire causes scorching or smoke deposits on Objects
Water	Water spill on objects leads to deformation, staining or breakdown
Pests	Pests gain access to Objects
Contamination	Dust, pollen or gas contaminate Objects
Radiation	Lack of UV filtering in lights or windows expose Objects to radiation
Incorrect Temperature or Relative humidity (RH)	Objects are exposed to significant fluctuations or deviating temperature or relative humidity

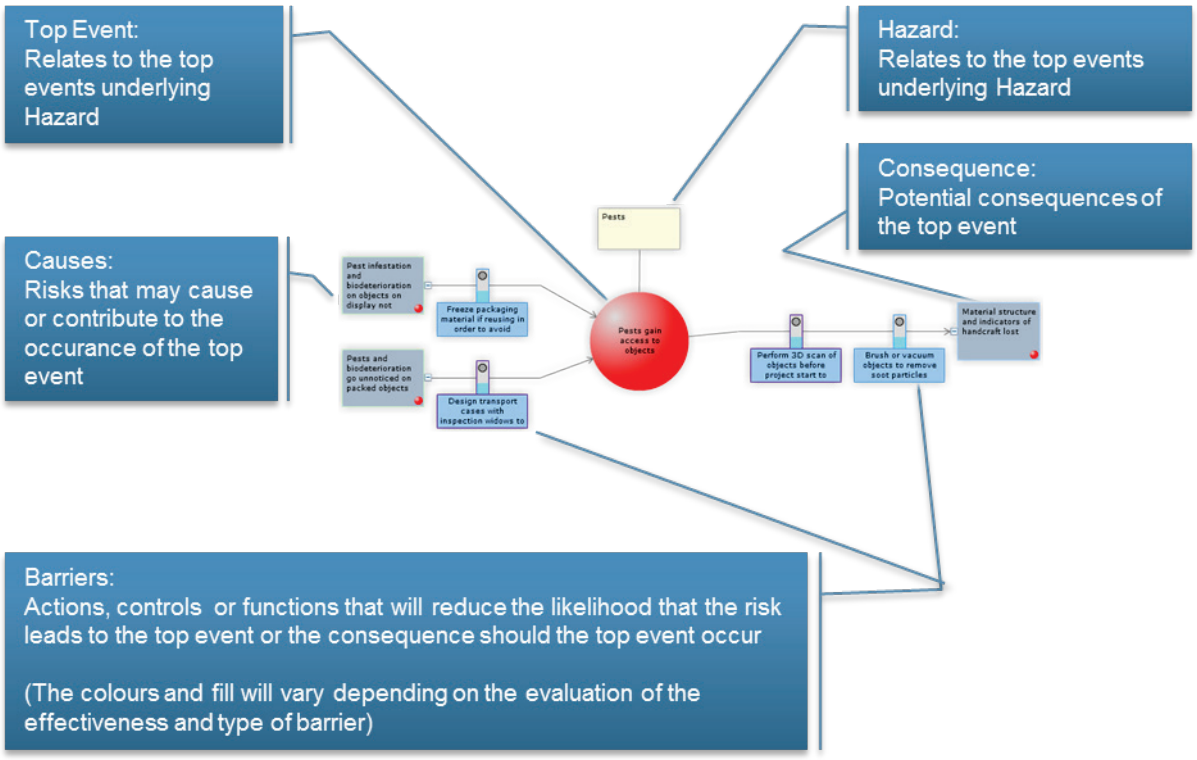


Figure 3 How to understand the bow tie diagrams[21]

[21] Bow Tie Diagrams are direct exports from the risk assessment tool used by the Expert Committee EasyRisk Manager™

Hazard: Direct Physical Forces

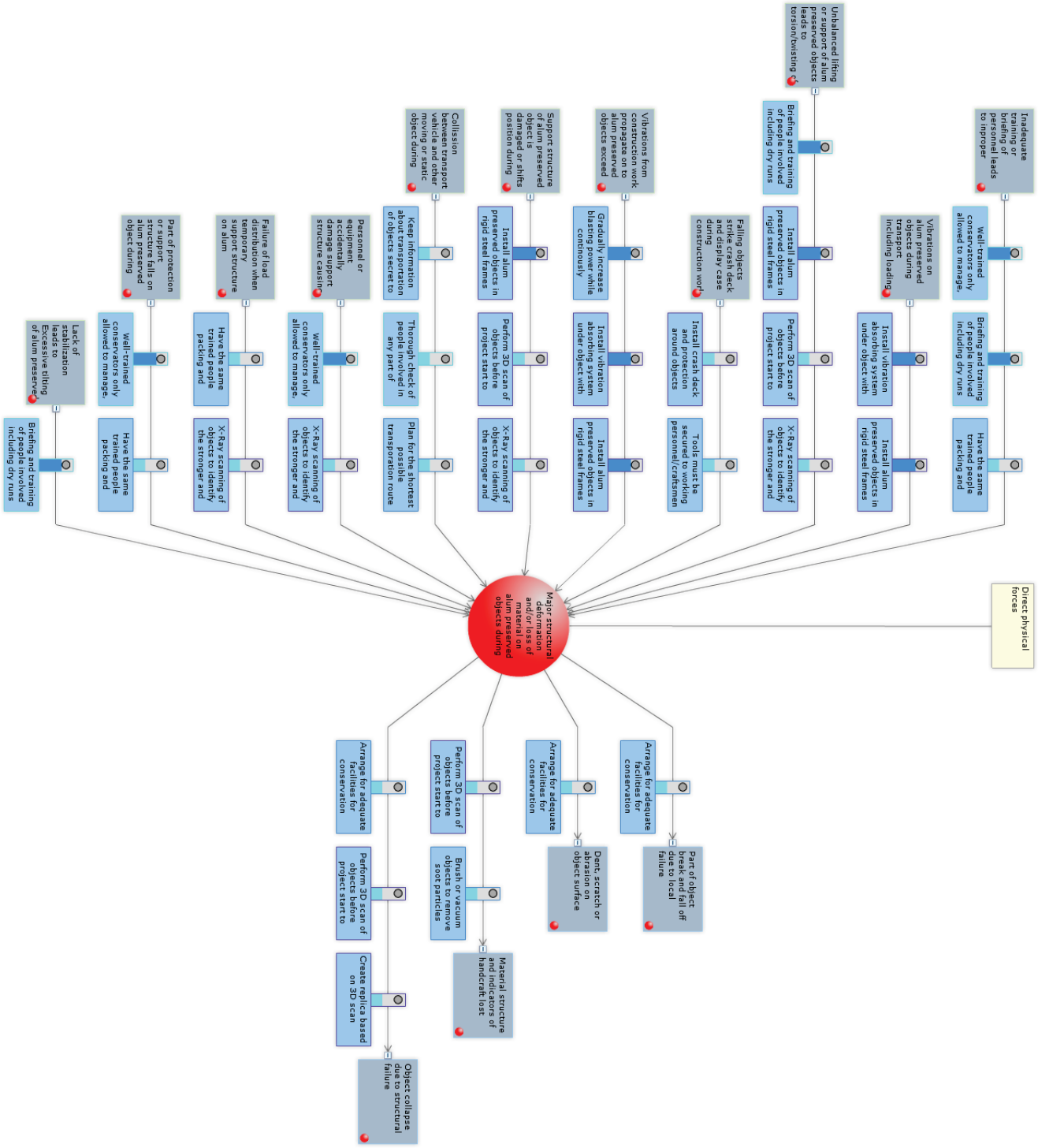


Figure 4 Major Structural deformation and/or loss of material on alum preserved Objects during project

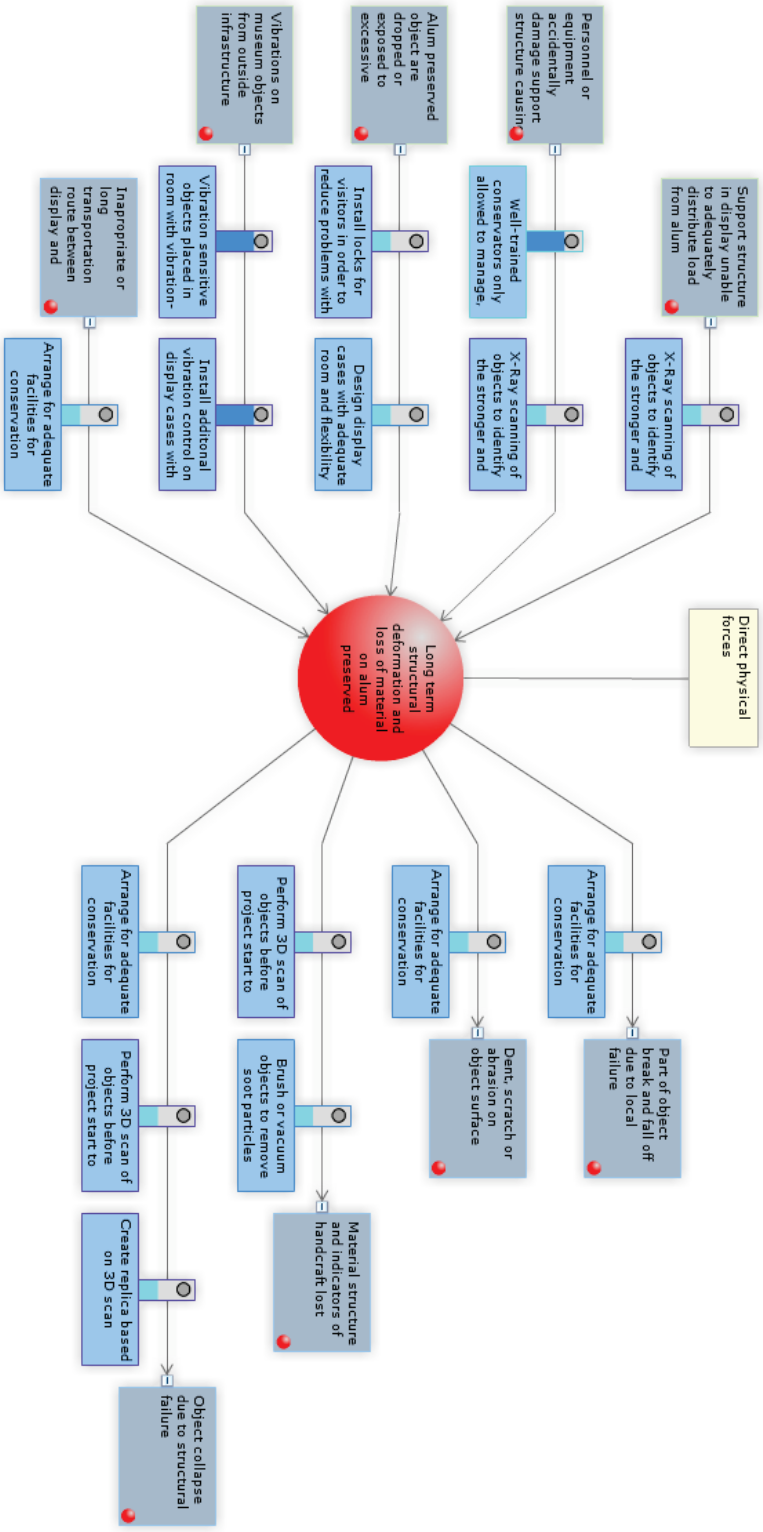


Figure 5 Long term structural deformation and loss of material on alum preserved Objects

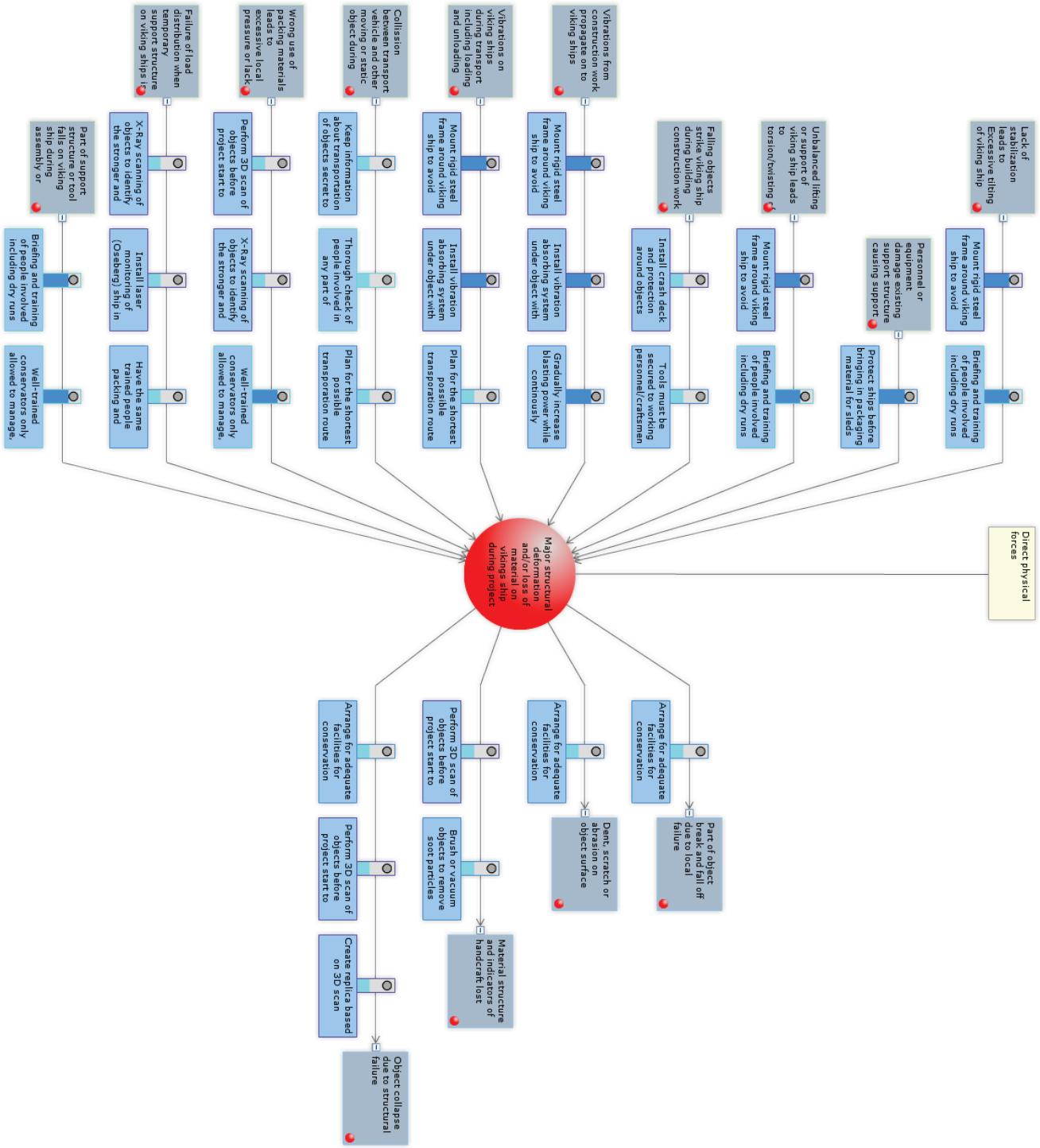


Figure 6 Major Structural deformation and/or loss of material on Viking ships during project

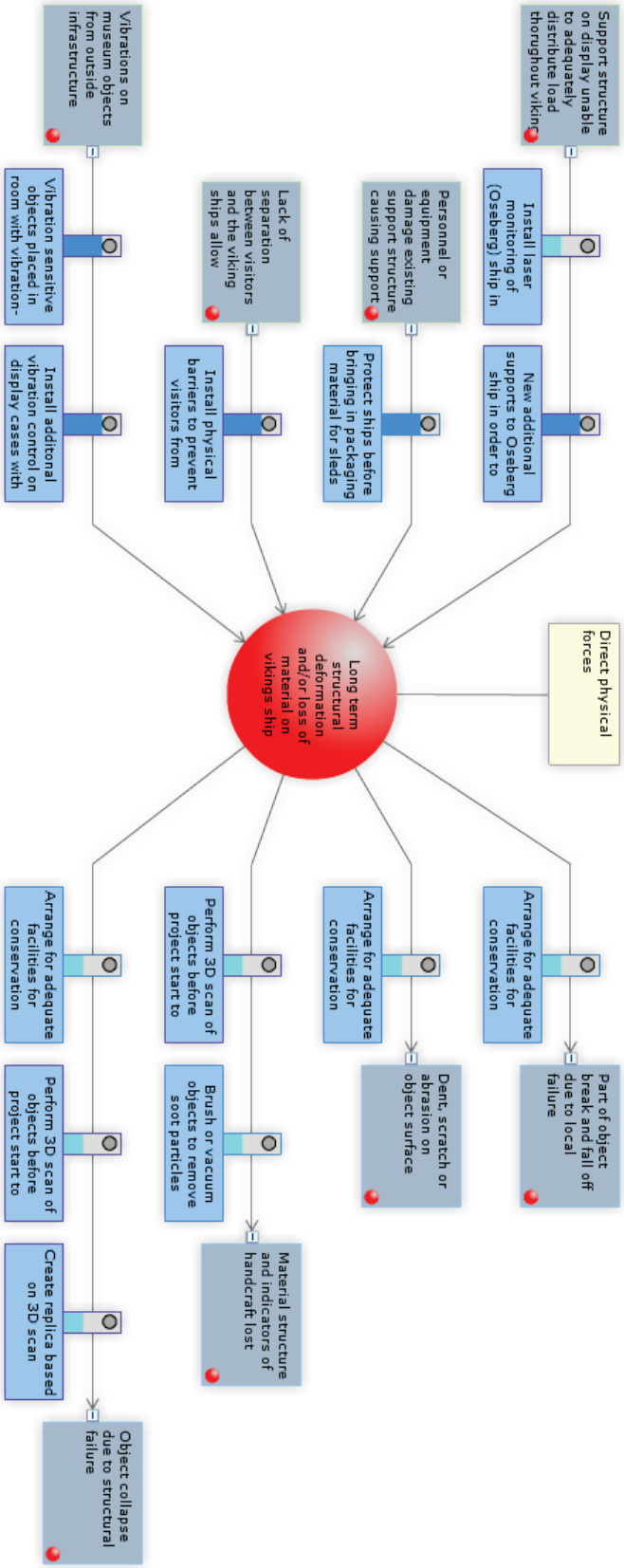


Figure 7 Long term structural deformation and/or loss of material on Viking ship

Hazard: Thievs, Vandals, Displacers

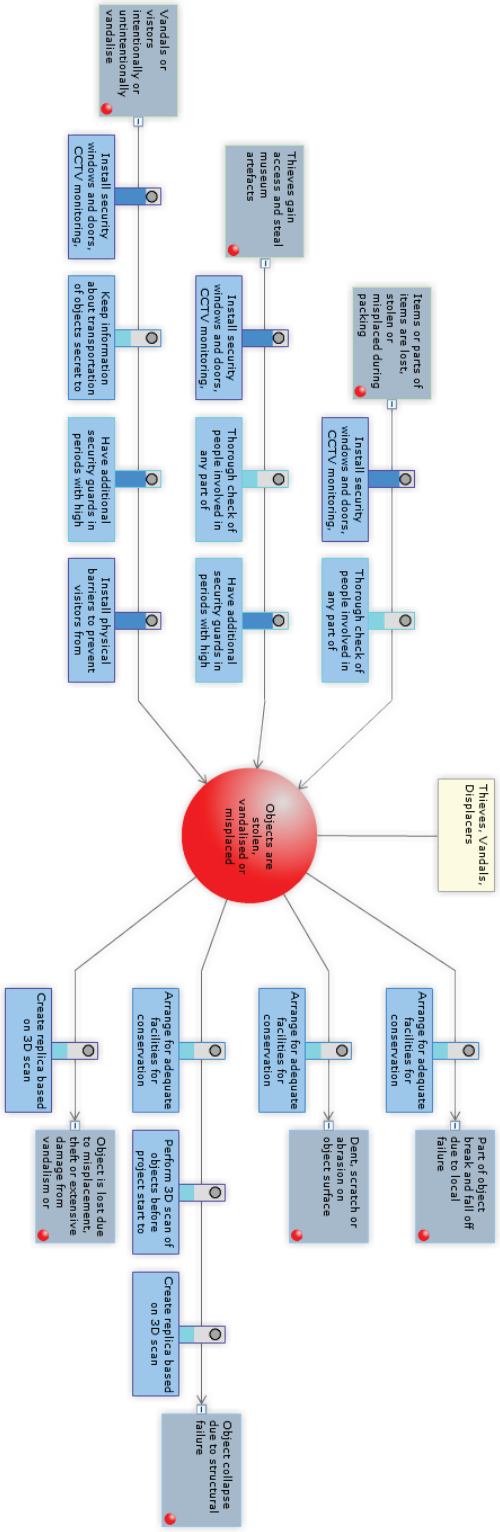


Figure 8 Objects are stolen, vandalized or misplaced

Hazard: Fire

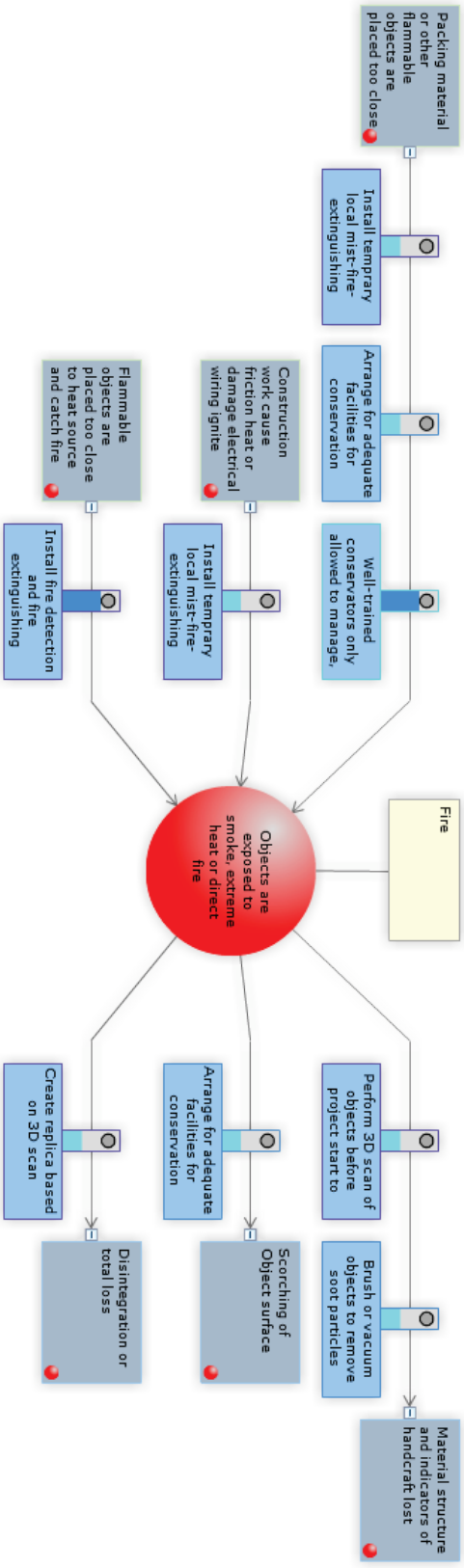


Figure 9 Objects are exposed to smoke, extreme heat or direct fire

Hazard: Water

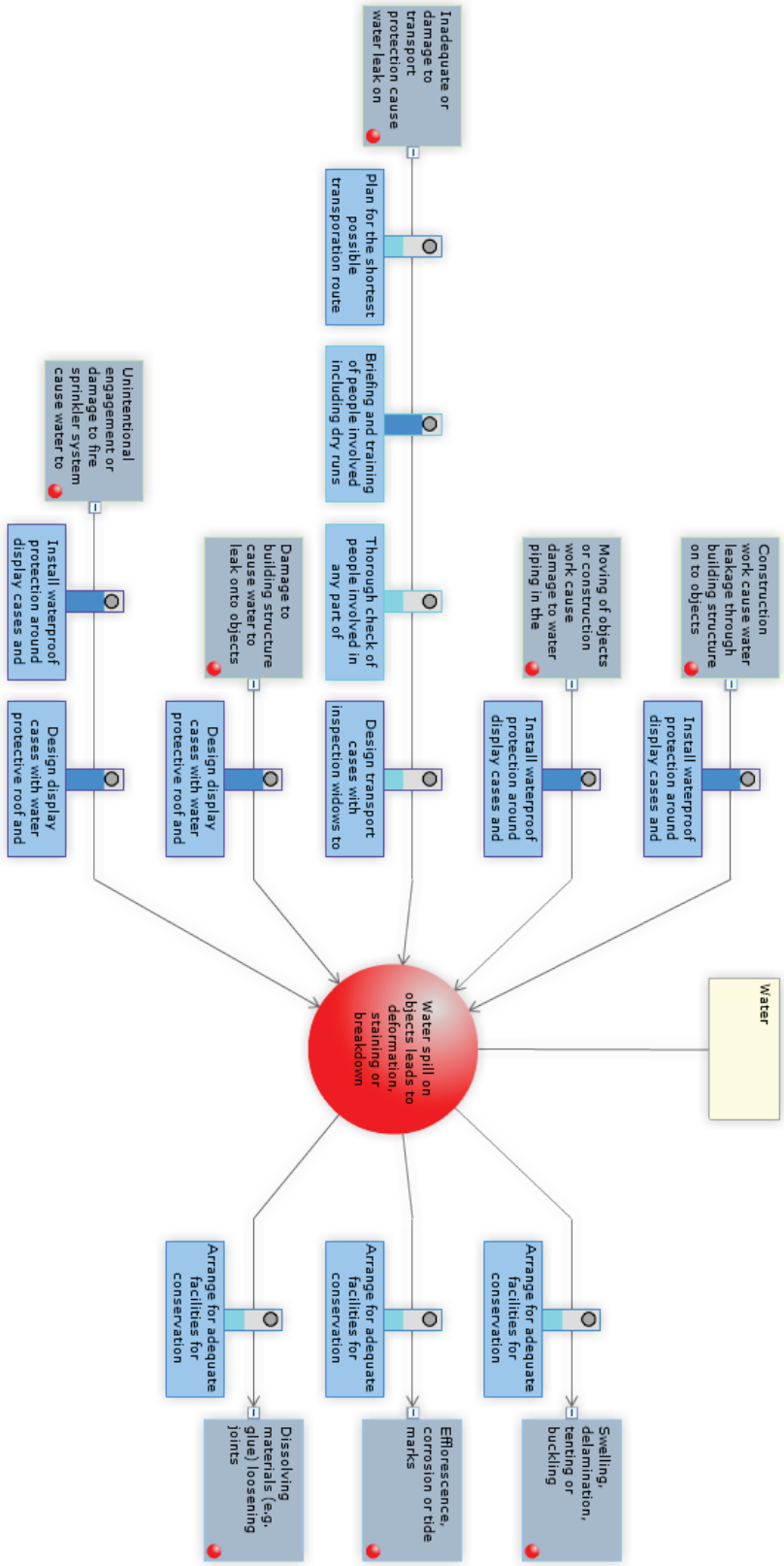


Figure 10 Water spill on Objects leads to deformation, staining or breakdown

Hazard: Pests

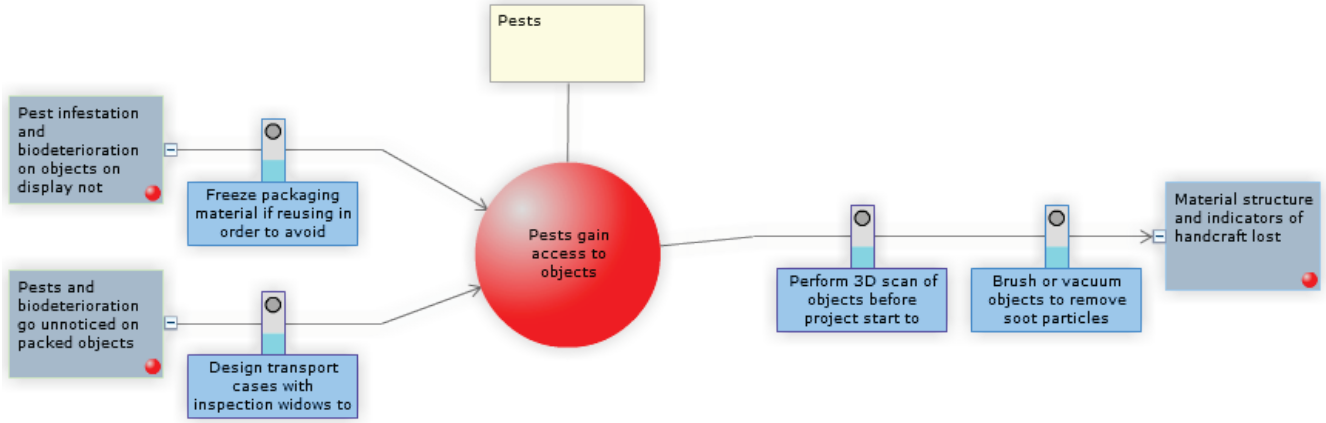


Figure 11 Pests gain access to Objects

Hazard: Contamination

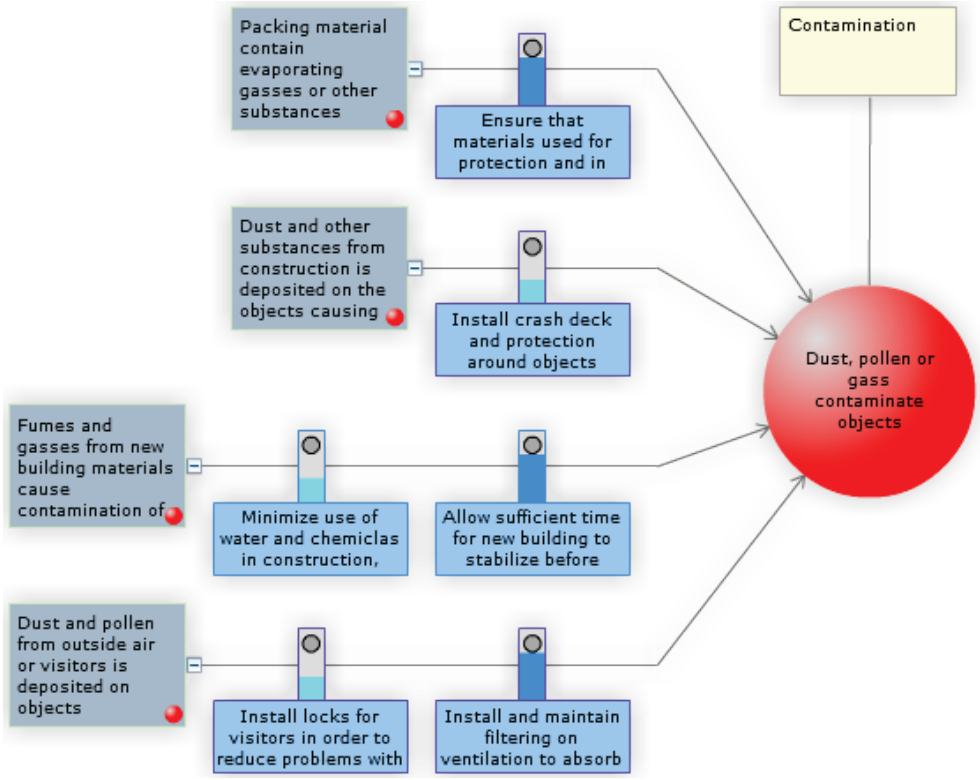


Figure 12 Dust, pollen or gass contaminate Objects

Hazard: Radiation

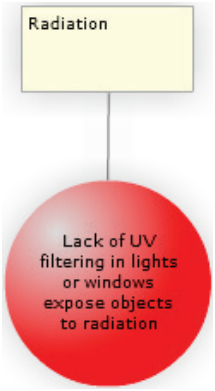


Figure 13 Lack of UV filtering in lights or windows expose Objects to radiation

Hazard: Incorrect temperature or relative humidity

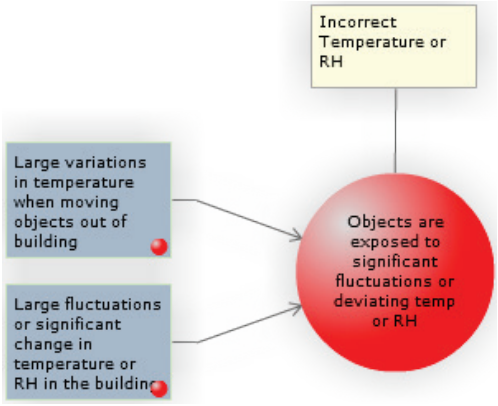


Figure 14 Objects are exposed to significant fluctuations or deviating temperature or relative humidity

APPENDIX 7
RISK ASSESSMENT RESULTS

This Appendix provides an extract of the results from the risk assessment performed by the Expert Committee. It presents the risk picture per scenario and per consequence category both long term and short term:

Scenario	Short description	Abbreviation
0	Remain in existing building at Bygdøy, no additional actions are taken	EX Bygdøy
1	New Building at Bygdøy followed by refurbishment of the existing building	NB Bygdøy
2	Refurbish and remain in existing building at Bygdøy	RE Bygdøy
3	Relocation to new building in Bjørvika	NB Bjørvika

The table below shows the risk matrixes for each scenario both on an aggregated level and per consequence category, Physical, Biological and Chemical change.
The numbers in the risk matrix corresponds to the respective risk ID in the table below.
The aggregated picture shows the highest criticality for each evaluated risk.

The list of assessed risk provides some general comment and notes from the discussion regarding the potential causes, consequences and how it may affect the different scenarios[22].
The first column of the list provides the risk ID which found in the risk in the matrixes.
The four columns to the right indicate criticality level of the risk in each of the consequence categories:

- Physical Short term – PH
- Biological Short term – BI
- Chemical Short term – CH
- Physical Long term – LPH
- Biological Long term – LBI
- Chemical Long term – LCH

The colour shows the assessed criticality towards the consequence class. The colours correspond to the colours in the matrix. No colour means that the risk is not considered to have consequence within this consequence category for the given scenario.

[22] The presented list is an extract of the most important elements and does not contain all risks evaluated in the discussions. A complete risk picture with risks, comments, actions, controls and barriers is collected in the risk management tool EasyRisk Manager™ used by the Expert Committee during the risk assessment.

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

Aggregated - Short Term Risk picture per Scenario

Scenario 0 EX Bygdøy				
Possible	R69	R60		
Unlikely				
Rare				
Extremely rare				R39 R40 R87
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

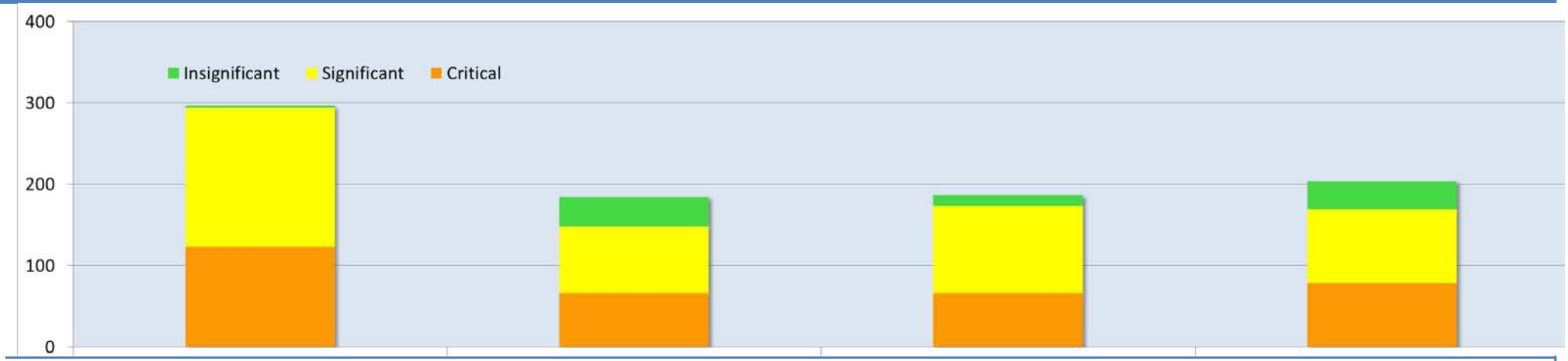
Scenario 1 NB Bygdøy				
Possible	R69			
Unlikely		R19 R57 R60 R77 R80 R91	R21 R83	
Rare	R79	R42 R59 R68 R86	R36 R37 R54 R78 R81	R87
Extremely rare	R47 R48 R55	R26 R41 R45 R89	R88 R90 R96	R38 R39 R40 R84
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Scenario 2, RE Bygdøy				
Possible	R69	R57 R59 R60	R83	
Unlikely	R79	R19 R91	R37 R78	
Rare	R47	R42 R45	R36 R54	R82
Extremely rare	R55	R41 R81	R90	R38 R39 R40 R87
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Scenario 3 NB Bjørvika				
Possible	R69			
Unlikely		R19 R57 R60 R77 R80 R91	R21 R81	R84 R87
Rare	R79	R26 R42 R48 R59 R68 R86	R36 R37 R54 R78 R88 R96	R40
Extremely rare	R47 R55	R41 R45 R89		R38 R39 R85 R90
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

Aggregated - Long term
Risk picture per Scenario



Possible		R60 R69	R76	
Unlikely		R49 R92 R93	R20	
Rare			R52	R39 R40 R87
Extremely rare	R94			R99
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Possible				
Unlikely		R60	R20	
Rare	R59	R69 R76		
Extremely rare	R94	R49 R92 R93	R50 R52 R99	R39 R40 R87
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Possible				
Unlikely		R60	R20	
Rare	R59	R69 R76 R92 R93		
Extremely rare	R94	R49	R52 R99	R39 R40 R87
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Possible				
Unlikely		R60	R20 R94	
Rare	R59	R69 R76		
Extremely rare		R49 R92 R93	R50 R52 R99	R39 R40 R87
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

Physical impact - Short term
Risk picture per Scenario

Scenario 0 EX Bygdøy

	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R69	R60		
Unlikely				
Rare				
Extremely rare				R39 R40 R87

Scenario 1 NB Bygdøy

	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R69			
Unlikely		R19 R57 R60 R77 R80 R91	R21 R83	
Rare	R79	R42 R54 R68 R86	R36 R37 R78 R81	R87
Extremely rare	R47 R48 R55	R26 R41 R45 R89	R88 R90 R96	R38 R39 R40 R84

Scenario 2, RE Bygdøy

	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R69	R57 R60	R83	
Unlikely	R79	R19 R91	R37 R78	
Rare	R47	R42 R45 R54	R36	R82
Extremely rare	R55	R41 R81	R90	R38 R39 R40 R87

Scenario 3 NB Bjørvika

	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R69			
Unlikely		R19 R57 R60 R77 R80 R91	R21 R81	R84 R87
Rare	R79	R26 R42 R48 R54 R68 R86	R36 R37 R78 R88 R96	R40
Extremely rare	R47 R55	R41 R45 R89		R38 R39 R85 R90

Physical impact - Long term
Risk picture per Scenario

Scenario 0 EX Bygdøy

	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible		R60 R69	R76	
Unlikely		R49 R92 R93	R20	
Rare		R52		R39 R40 R87
Extremely rare	R94			R99

Scenario 1 NB Bygdøy

	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible				
Unlikely		R60	R20	
Rare		R69 R76		
Extremely rare	R94	R49 R52 R92 R93	R50 R99	R39 R40 R87

Scenario 2, RE Bygdøy

	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible				
Unlikely		R60	R20	
Rare		R69 R76 R92 R93		
Extremely rare	R94	R49 R52	R99	R39 R40 R87

Scenario 3 NB Bjørvika

	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible				
Unlikely		R60	R20 R94	
Rare		R69 R76		
Extremely rare		R49 R52 R92 R93	R50 R99	R39 R40 R87

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

Biological impact - Short term
Risk picture per Scenario

Scenario 0 EX Bygdøy	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R60 R69			
Unlikely				
Rare				
Extremely rare				R40
Prob Cons				

Scenario 1 NB Bygdøy	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R69			
Unlikely	R19 R57 R60			
Rare	R68		R54	
Extremely rare	R47 R48 R55	R45		R40
Prob Cons				

Scenario 2, RE Bygdøy	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R57 R60 R69			
Unlikely	R19			
Rare	R47	R45	R54	
Extremely rare	R55			R40
Prob Cons				

Scenario 3 NB Bjørvika	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R69			
Unlikely	R19 R57 R60			
Rare	R48 R68		R54	R40
Extremely rare	R47 R55	R45	R85	
Prob Cons				

Biological impact – Long term
Risk picture per Scenario Long term

Scenario 0 EX Bygdøy	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible	R60	R69		
Unlikely		R49 R92		
Rare			R52	R40
Extremely rare				R99
Prob Cons				

Scenario 1 NB Bygdøy	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible				
Unlikely	R60			
Rare		R69		
Extremely rare		R49 R92	R50 R52	R40
Prob Cons				

Scenario 2, RE Bygdøy	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible				
Unlikely	R60			
Rare		R69 R92		
Extremely rare	R99	R49	R52	R40
Prob Cons				

Scenario 3 NB Bjørvika	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage
Possible				
Unlikely	R60			
Rare		R69		
Extremely rare		R49 R92	R50 R52	R40
Prob Cons				

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

Chemical impact – Short term
Risk picture per Scenario Long term

Scenario 0 EX Bygdøy

Possible	R69	R60		
Unlikely				
Rare				
Extremely rare				R40
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Scenario 1 NB Bygdøy

Possible	R69			
Unlikely	R19	R57 R60		
Rare	R68	R42 R54 R59		
Extremely rare	R47 R48 R55	R41 R45		R40
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Scenario 2, RE Bygdøy

Possible	R69	R57 R59 R60		
Unlikely	R19			
Rare	R47	R42 R45 R54		
Extremely rare	R55	R41		R40
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Scenario 3 NB Bjørvika

Possible	R69			
Unlikely	R19	R57 R60		
Rare	R68	R42 R48 R54 R59		R40
Extremely rare	R47 R55	R41 R45	R85	
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Chemical impact – Long term
Risk picture per Scenario Long term

Scenario 0 EX Bygdøy

Possible		R60 R69		
Unlikely	R93	R49 R92		
Rare		R52		R40
Extremely rare				R99
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Scenario 1 NB Bygdøy

Possible				
Unlikely		R60		
Rare	R59	R69		
Extremely rare	R93	R49 R52 R92	R50 R99	R40
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Scenario 2, RE Bygdøy

Possible				
Unlikely		R60		
Rare	R59 R93	R69 R92		
Extremely rare		R49 R52	R99	R40
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Scenario 3 NB Bjørvika

Possible				
Unlikely		R60		
Rare	R59	R69		
Extremely rare	R93	R49 R52 R92	R50 R99	R40
Prob Cons	Superficial Damage	Minor Damage	Significant Damage	Extensive Damage

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
R-0019	Direct physical forces	Inadequate training or briefing of personnel leads to improper handling of alum preserved object during packing or transport	Sleds, wagon, animal head posts	Excessive local pressure.	Assume that people are trained in handling of fragile objects. Not relevant for base scenario. But relevant in all other scenarios	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0020	Direct physical forces	Support structure in display unable to adequately distribute load from alum preserved object weight caused by gravity	Sleds, wagon, animal head posts. Long term exposure		Relevant in all scenarios. Reason for it happening will most likely be chemical, but the consequence will be physical.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0021	Direct physical forces	Vibrations on alum preserved objects during transport including loading and unloading	Vibrations from moving over uneven surface (moving inside/out of building, on transport route, and when moving into new building)	Loosening of joints. Potentially loose powdery material. Not expected to lose large fragments. Repairable damage and may have significant effects on the object. Both the breaking off and the impact of landing of fragments may cause damage that may have significant effect.	Not relevant for EX Bygdøy (baseline). Assume that objects are mounted on vibration controlled surface before moving starts. Air ride suspension truck. Pneumatic tyres inside building e.g. Adequate number of trained and briefed people present to assist and control during the move. (not too few, not too many) Rehearsed with empty case before actual move.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0026	Direct physical forces	Lack of stabilization leads to Excessive tilting of Viking ship during transport	Excessive tilting of object when exiting building or loading onto transport unit Excessive tilting of object due to inclinations on transport route Lack of or failure of stabilization mechanism (gyro) Excessive speed during moving doesn't give adequate time to adjust tilting Tilting/movement inside the transport frame.	Loosening of joints. No deformation of the structure.	Lowering ship down to ground level. The lowering must be tested and practised with a simulated load. NB Bygdøy: Some sort of levelling platform (e.g. hoover craft platform) on prepared route. NB Bjørvika: Truck with hydraulic levelling platform used to level out gradient to Dronningen, onto and off barge and into new building. Entering the new building is done in reverse of the process of leaving existing building.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0036	Direct physical forces	Wrong use of packing materials leads to excessive local pressure	Sleds, wagon, animal head posts Packing materials not adequately tailored to object surface	Over packing leading to local pressure and deformation of part of the	Same packing for NB Bygdøy and NB Bjørvika and RE Bygdøy. Conservators from the Viking ship museum in	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
		or lack of support on alum preserved objects	Packing material not correctly mounted or placed Support structure not able to distribute load The weight of packing materials are too heavy and cause excessive pressure on object	surface structure. Damage during unpacking. See also R-56	charge of selection of materials and all packing. ONLY use of inert materials for packing without off gassing. (ODDY test) Select types of foams or sheeting (Tyvek) allowing transmission of moisture and air based on experience from other relocation processes. Objects are not left in crates more than necessary and are not left in packing more than two years. Uncertainty regarding acidic deposits on the glass of the wall mounted display cases and objects.				
R-0037	Direct physical forces	Personnel or equipment damage existing support structure causing support failure of Viking ship	Support structure is accidentally repositioned or damaged causing object support failure. People accidentally damage support structure during packing and preparation Moving or construction equipment strike the support structure.	Local Deformation of the structure. Repairable, but may have significant influence on the object. Oseberg most exposed and most vulnerable. Gokstad less vulnerable. Thune is less exposed due to location and weight.	Not relevant for EX Bygdøy (Baseline) Ships are protected before moving materials past them (e.g. physically protected against contact from other moving support structures or objects before any relocation starts). Relevant for Oseberg when moving smaller objects out of the building before moving Viking ships, or when transporting tools or debris for modifying existing building.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0038	Thieves, Vandals, Displacers	Items or parts of items are lost, stolen or misplaced during packing	Small items are misplaced or lost among other packing materials. Too much activity on-going at one time Unstructured packing process. Unclear assignment of responsibility. Lack of control lists. Lack of tidiness - packing material and garbage not appropriately managed. Lack of space to perform packing.	Size of collection reduced. Objects or parts of objects are removed by project members/external contractors and sold illegally	Do we expect "sikkerhedsgodkendelse/ren straffeattest" and description and training in work flow including administrative processes? Physical guards on entry points with access control, access protocols, surveillance of work on most relevant object.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0039	Thieves, Vandals, Displacers	Thieves gain access and steal museum artefacts	Security guards not appropriately stationed to detect intruders Lack of or improper placing of surveillance cameras in the buildings. Packing cases, materials obscure overview of objects Opening in buildings.	Smaller objects most relevant. Impact difficult to measure. If item is lost or stolen it is considered as total loss	Long term likelihood slightly higher for EX Bygdøy than for other scenarios due to lack of security arrangements in existing building. Exhibition design must deter/protect against theft	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
R-0040	Thieves, Vandals, Displacers	Vandals or visitors intentionally or unintentionally vandalise museum artefacts	Security guards not appropriately stationed to detect intruders. Lack of or improper placing of surveillance cameras in the buildings. Protection in existing building limited, several objects are not physically separated from visitors security guards not able to constantly overview all parts of the building. Packing cases, materials obscure overview of objects New openings in the building structure are created as part of the project providing access for intruders		Transport in unmarked vehicles. Exhibition design must deter/protect against vandalism.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0041	Fire	Packing material or other flammable objects are placed too close to heat source and catch fire	Flammable packing material placed too close to warm objects (e.g. oven/heater) Smoking Damage to wiring in electrical appliances ignite fire (lighting, equipment used in project). Friction during transport cause excessive heat.	Physical impact from CO2 from fire extinguisher. Biological degradation because of soaking. Chemical damage due to smoke deposits and soaking.	Smoking and hot working procedures should be in place. Heated spatula could be relevant to seal packing. Inspection lamps. Local fire detection in place in areas with new heat sources.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0042	Fire	Construction work cause friction heat or damage electrical wiring ignite packing material or other flammable objects	Friction or sparks from cutters or welding equipment used when dismantling building structure ignite packing material or other flammable objects (e.g. for moving Viking ships) Defective or damage to wiring in building or electrical appliances used in construction	Physical impact from CO2 from fire extinguisher. Biological degradation because of soaking. Chemical damage due to smoke deposits and soaking.	NB Bygdøy and NB Bjørvika - Only relevant for Viking ships. Hot working procedure in place. Local fire detection systems in areas with construction work. Install temporary local mist system. Fire extinguishers. Likelihood higher (Med) for RE Bygdøy.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0045	Water	Construction work cause water leakage through building structure on to objects	Work on the building requires opening up the building structure. This may cause water to leak on to objects.	Minor leaks through protective casing/ crash deck around objects. Water will find its own path through the building depending on structure,	NB Bjørvika: Viking ships are left in situ and protected when construction starts. NB Bygdøy: Barrier is created between the construction area and the objects. Class A objects are left in situ. RE Bygdøy - all objects are still in the building.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
				wind, and amount of water.	Small objects can be temporarily moved to temporary storage.				
R-0047	Water	Moving of objects or construction work cause damage to water piping in the building leading to water spill on objects	Plumbing, water based heating.			PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0048	Water	Inadequate or damage to transport protection cause water leak on objects when transporting objects outdoor	Lack of water resistant packing. Lack of adequate roofing in lading area. Large variations in temperature cause condensation on objects when moving from cold to warm area. High RH level outdoors when moving object out of building.	Object can be repaired without significant effects; repairs may be visible but not extensive. Patchy colour changes discoloration Minor growth on surface if not detected in time. Minor local structural deformation	Packing material water resistant. Damage to packing material may lead to minor leakage EX Bygdøy, only selected objects will be moved, move can be done on a day without expected rain.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0049	Water	Damage to building structure cause water to leak onto objects	Lack of long term building maintenance. Defects in building construction. Extreme weather conditions causing damage to building structure.	Water leak through building structure into display case or on Viking ships. Consequence less than for R50 - fire sprinkler system. Most likely limited to parts of the collection.	NB Bygdøy, NB Bjørvika new display cases includes protection from water leakage. RE Bygdøy, display cases are improved to reduce likelihood of water damage	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0050	Water	Unintentional engagement or damage to fire sprinkler system cause water to pour on objects	Lack of protection or interlock on fire sprinkler system. Lack of maintenance of fire sprinkler system. Poor design or installation of the system.		EB Bygdøy - No fire sprinkler NB Bygdøy, Bjørvika - new misting system in critical zones RE Bygdøy - new fire sprinkler misting system in critical zones	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0052	Pests	Pest infestation and bio deterioration on objects on display not detected in time	Mice or other pests enter the building through openings made in order to move the objects. Openings made during refurbishment (e.g. ventilation, replacing windows, doors etc.) Leaving doors or other openings open for too long allow pests to	Viking ships and objects in wall mounted display cases are particularly vulnerable. Viking ships are vacuumed once a year. Discolouration, etching, weakening, powdering of	Expected that improvement of display cases will reduce likelihood of pests gaining access	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
			enter building and gain access to objects. Improper control of the openings and lack of access to areas around display cases to detect bio deterioration on material in display cases that may affect objects. Biological waste is left in areas where people are going in and out of the museum	part of materials.					
R-0054	Pests	Pests and bio deterioration go unnoticed on packed objects	Leaving doors or other openings open for too long allow pests to enter building and gain access to objects. Improper control of the openings. Biological waste is left in areas with packed objects Packed objects left without inspection for longer periods. Packed objects left in damp areas. Damp packaging material is used.			PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0055	Contamination	Packing material contain evaporating gasses or other substances causing contaminating of objects	Inadequate control and testing of packing material Grease, oil or other substances used in the rigid transportation frames. Hydraulic liquids used in stabilization and anti-vibration mechanisms.	Chemical effects minor surface alterations. Physical effects like patchy colour changes.	See also risk R-36 Same packing for NB Bygdøy and NB Bjørvika and RE Bygdøy. Conservators from the Viking ship museum in charge of selection of materials and all packing. ONLY use of inert materials for packing without off gassing. (ODDY test) Select types of foams or sheeting (Tyvek) allowing transmission of moisture and air based on experience from other relocation processes. Objects are not left in crates more than necessary and are not left in packing more than two years. Uncertainty regarding acidic deposits on the glass of the wall mounted display cases and objects	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0057	Contamination	Dust and other substances from construction is deposited on the objects causing	Concrete, plaster, wood, paint, glue etc. whirled or spilled during construction work. Cutting in concrete walls to create	Light surface soiling. Some chemical soiling.	Sealing off part of building during opening building will minimize the spreading of dust. RE Bygdøy will expose objects for long time	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
		contamination	new openings. Replacing parts of existing building (doors, windows, wall mounted display cases). Repainting, installing or replacing ventilation.		and objects expected to be left in situ while refurbishing				
R-0059	Contamination	Fumes and gasses from new building materials cause contamination of objects	The objects will be exposed to a series of building materials when refurbishing existing building, or moving into a new building. Fumes and gasses from new display cases.		Materials in new building and in display cases must be carefully selected and tested and methods for installation. Minimize use of water and chemical in construction. Allow adequate time for building to be left to stabilize before objects are moved into it. (FIXED stabilization period) RE Bygdøy means that objects will be in the building exposed to the building materials. RB Bygdøy - may have higher short term effects (med and same probability and same long term effects as NB).	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0060	Contamination	Dust and pollen from outside air or visitors is deposited on objects	Short term: May be deposited on packing material when it is first used, or when objects are unpacked after transportation. Inadequate packing or damage may cause dust to accumulate on objects inside packing. Long term: Lack of filtering in ventilation. Pollen and dust enters building through ventilation or other openings (doors/windows) and deposit on objects. Dust from visitors. Lack of adequate cleaning. Direct openings from outside to display area.	Dust on objects containing substances which increase long term rate of decay. Discolouration and bio degradation (organic substances, pollen)		PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0068	Incorrect Temperature or RH	Large variations in temperature when moving objects out of building	High outside temperature (25-30 degrees) in summer. Low outside temperature in winter (-10-25 degrees C).		NB Bygdøy/Bjørvika Moving during spring or autumn. Insulated casing -> Rate of change is low due	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
					to insulation Objects should be left packed in insulated packing for 24 hours after bringing into the new building to acclimatize.				
R-0069	Incorrect Temperature or RH	Large fluctuations or significant change in temperature or RH in the building cause damage to the objects	Short term: When building is opened up for moving objects out. Refurbishment of existing building. E.g. windows are replaced, doors, ventilation are installed etc. Objects require temperature and humidity control. Control system failure may lead to too high or too low humidity level in display cases. Long term change in temperature fluctuation pattern when moved to new building or when existing building is refurbished The Viking ships seem to be in sync with the temperature and humidity fluctuations in the existing Viking Ship Building. Moving to a new environment, or changing the temperature and humidity regulation in the existing building may have adverse effects	Sensitivity to temperature and humidity change is low. Moisture content of the ships changes over the year without significant sign of visible change e.g. cracks or flaking.	RE Bygdøy - highly relevant refurbishment will last for long period. Not a big change to existing situation. Low risk issue Low/v-Low/ v-Low Change in temperature humidity fluctuation pattern when moved to new building or when existing building is refurbished.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0076	Direct physical forces	Support structure on display unable to adequately distribute load throughout Viking ship hull caused by gravity	Lack of improvement of support points or wrong placement of additional support points. Long term sagging of structure.	Few hairline cracks. Potential loosening of joints. Long term effect.	Given support as today (2012 at Bygdøy). NB Bygdøy / NB Bjørvika: Additional support or new improved support transverse and on the oar forks. EB Bygdøy refurbished: additional support will be provided transverse and on the oar forks.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0077	Direct physical forces	Unbalanced lifting or support of Viking ship leads to torsion/twisting of ship structure	Wrong assembly or design of support frame. Method of application is not adequate. Critical point: Damage during mounting and dismounting on steel frame. Unbalanced lifting due to failure of lifting equipment or lack of	Oseberg is sensitive due to the combination of new and old materials. Thune has not been dismantled and is less sensitive than Oseberg due to original ship materials and construction. Gokstad is less sensitive.	Rigid steel frame. Inert material supporting throughout the structure. Removable / detachable elements inside will be taken out (Mast, deck planking, gangway etc.) NB Bygdøy - Only Gokstad will be moved (transport category B) NB Bjørvika - all ships will be moved. Refurbish Bygdøy - not relevant unless	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
			coordination	(Rigid frame for the Viking ships may be necessary during the refurbishment to install vibration absorber - vibration risk must be balanced against the potential impacts and risk related to mounting the ships in rigid frames)	vibration control mechanism needs to be installed under Viking Ship.				
R-0078	Direct physical forces	Falling objects strike Viking ship during building construction work	Work may have to be done above Viking ships when refurbishing the Viking ship building. During this phase items like building equipment or tools may fall down and strike the Viking ships.			PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0079	Direct physical forces	Vibrations from construction work propagate on to Viking ships	Vibrations from cutting machinery when tearing down wall for relocation of large objects (e.g. Viking ships). Vibrations from cutting machinery when refurbishing existing building, e.g. opening holes for installing ventilation, tearing down building parts for improvement of display conditions and visitor facilities (shop, ticket boot etc.)		Objects are mounted onto stable frames with vibration isolation before construction starts. New Building is finished and stable before objects are moved into them. Uncertainty whether the wall in the 4th wing is loadbearing and able to withstand dismantling. The construction of the 4th wing is not directly connected to the Oseberg wing. (D03.03)	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0080	Direct physical forces	Vibrations on Viking ships during transport including loading and unloading	Vibrations from moving over uneven surface (moving inside/out of building, on transport route, and when moving into new building)	Loosening of joints. Potentially loose powdery material. Not expected to lose large fragments. Repairable damage but no significant effects on the object.	Refer to R-021 But effect on ships lower than alum treated objects. Not relevant for EX Bygdøy (baseline). Assume that ships are mounted on vibration controlled surface before moving starts. E.g. Air ride suspension truck or similar, air floating device for moving to truck. Adequate number of trained and briefed people presents to assist and control during the move. (not too few, not too many) Rehearsed and measured with similar load before actual move.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0081	Direct	Unbalanced lifting or	Wrong assembly or design of	(Rigid frame under the	Ref R-77 But higher consequence	PH LPH	PH LPH	PH LPH	PH LPH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
	physical forces	support of alum preserved objects leads to torsion/twisting of structure	support frame. Unbalanced lifting due to failure of lifting equipment or lack of coordination	display cases may be necessary during the refurbishment to install vibration absorber - vibration risk must be balanced against the potential impacts and risk related to mounting the case in rigid frames)	Rigid steel frame. Inert material supporting throughout the structure. Removable / detachable elements inside will be taken off (e.g. wheels on wagon) NB Bygdøy - No movement but vibration reducing frame will be installed. NB Bjørvika - all objects will be moved. Refurbish Bygdøy - not relevant unless vibration control mechanism needs to be installed under Viking Ship. RE Bygdøy: If vibrations control frame is to be installed under display case, lack of rigidity in display case may lead to torsion/twisting	BI LBI CH LCH	BI LBI CH LCH	BI LBI CH LCH	BI LBI CH LCH
R-0082	Direct physical forces	Falling objects strike crash deck and display case during construction work	Work may have to be done above display cases when refurbishing the Viking ship building. During this phase items like building equipment or tools may fall down and strike the display case, causing damage to the display case and the object.	Glass shatters.	NB Bygdøy, NB Bjørvika sensitive objects are moved out of the existing building before construction starts Only relevant for Refurbished Building Bygdøy. Probability V-L and Consequence Very high. Cases and objects protected in situ with crash deck above them.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0083	Direct physical forces	Vibrations from construction work propagate on to alum preserved objects exceed threshold	Threshold = (vpeak,95 =< 0.5 mm/s) Vibrations from heavy cutting machinery when tearing down wall for relocation of large objects (e.g. Viking ships). Vibration from construction on new building at Bygdøy. Vibrations from heavy cutting machinery when refurbishing existing building, e.g. opening holes for installing ventilation, tearing down building parts for improvement of display conditions and visitor facilities (shop, ticket	Loosening of joints. Potentially loose powdery material. Not expected to lose large fragments. Repairable damage and may have significant effects on the object. Both the breaking off and the impact of landing of fragments may cause damage that may have significant effect. NB Bygdøy: Vibrations	Related to R-79 & R21 NB Bjørvika: Alum preserved objects are mounted onto stable frames with vibration isolation and transported out of the building before construction starts. New Building is finished and stable before objects are moved into them. Control: Measure vibrations during construction - stop construction work if threshold is exceeded. Implement additional protection if possible. Gradually increasing blasting power while measuring vibrations to assure threshold is not exceeded.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
			boot etc.)	propagating from construction work on new building to the alum preserved objects (e.g.). RE Bygdøy: Consequences of vibrations propagating to the objects higher than for NB due to longer exposure time and work closer to the objects	NB Bygdøy. Alum preserved objects are left in situ during construction on new building.				
R-0084	Direct physical forces	Support structure of alum preserved object is damaged or shifts position during transport failing to provide adequate support	If support structure is not properly secured, moving and lifting the object may cause shifting of the support structure. Lifting the support structure may cause local damage to the support material, leading to partial or overall loss of support	Crushing/deformation of surface structure. Objects are so fragile that they might be crushed even if they are properly secured.		PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0085	Direct physical forces	Collision between transport vehicle and other moving or static object during transport to Bjørvika	Impact from collision with foreign object (car/bike/other) Inadequate clearing between transport frame and surrounding structures on transport route cause collision (bridges, buildings, lamp or sign posts etc.)		Engine failure	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0086	Direct physical forces	Wrong use of packing materials leads to excessive local pressure or lack of support on Viking ships	Packing materials not adequately tailored to object surface Packing material not correctly mounted or placed Support structure not able to distribute load The weight of packing materials are too heavy and cause excessive pressure on object	Inappropriate packing leads to local pressure and deformation of the structure Thune and Oseberg is equally sensitive.	Same packing for NB Bygdøy and NB Bjørvika. Conservators from the Viking ship museum in charge of selection of materials and all packing. ONLY use of inert materials for packing without off gassing. (ODDY test) Select types of foams or sheeting (Tyvek) allowing transmission of moisture and air based on experience from other relocation processes. Objects are not left in crates more than necessary and are not left in packing more than two years. Rigid steel frame. Inert material supporting throughout the structure.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
					Removable / detachable elements inside will be taken out (Mast, deck planking, gangway etc.) NB Bygdøy - Only Gokstad will be moved (transport category B) NB Bjørvika - all ships will be moved. Refurbish Bygdøy - not relevant. Packing material not needed.				
R-0087	Direct physical forces	Personnel or equipment accidentally damage support structure causing damage to alum preserved objects	During packing/preparation/construction work/maintenance Moving of construction equipment strikes the support structure or display cases. Display case or support structure is accidentally repositioned or damaged causing object support failure. People accidentally damage support structure during packing and preparation or during cleaning and inspection.	Crushing/deformation of surface structure. Objects are so fragile that part of the structure might be crushed if support structure is damaged.	Same as R0084 but relevant long term and for objects in situ. Likelihood of damage slightly higher long term for Ex Building Bygdøy due to the challenging access in the current display cases. Long term for new and refurbished building expect some improvement of display case to facilitate easier access for cleaning and maintenance.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0088	Direct physical forces	Failure of load distribution when temporary support structure on alum preserved objects is removed	Object or part of an object may have partly loosened and is leaning on temporary support structure installed on alum preserved objects to provide additional support during construction work or transportation. When removed the object may break or fall off if adequate control is not in place when removing the temporary support.	Not expected to lose large fragments. Repairable damage and may have significant effects on the object. Both the breaking off and the impact of landing of fragments may cause damage that may have significant effect.	RE Bygdøy existing support structure only (improvements to permanent support if necessary) NB Bygdøy some additional support installed before objects are moved. NB Bjørvika: temporary support structure	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0089	Direct physical forces	Failure of load distribution when temporary support structure on Viking ships is removed	Due to forces exerted on the ship hull during construction work or transport part of the structure may be leaning on temporary support structure. Lack of adequate attention when removing this support structure may lead to lack of adequate support on part of the structure.	Few hairline cracks. Potential loosening of joints.		PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
R-0090	Direct physical forces	Part of protection or support structure falls on alum preserved object during assembly or disassembly of the structure	Wrong assembly or disassembly sequence of support structure or protection cause part to fall on alum preserved object... Part of support structure damage display case or alum preserved object when installed or removed. Can be caused by undiscovered damage caused by prior incident	Impact may cause irreversible deformation of part of the surface.	Mounting and removal of support structure managed by experienced personnel from the Museum	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0091	Direct physical forces	Part of support structure or tool falls on Viking ship during assembly or disassembly of the support structure and packing	Wrong assembly or disassembly sequence of support structure or protection cause part to fall on alum preserved object... Part of support structure damage display case or alum preserved object when installed or removed. Can be caused by undiscovered damage caused by prior incident	Damage where repair is possible without significant effect on the object. Potential loosening of joints.	Ref R97	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0092	Direct physical forces	Lack of separation between visitors and the Viking ships allow visitors to touch Viking ship structure while on display	Lack of space. Lack of protection between visitors and the Viking ships			PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0093	Direct physical forces	Alum preserved object are dropped or exposed to excessive pressure during cleaning and maintenance	Accessibility to the objects inside display case can be difficult, leading to challenge wrt cleaning of the objects. Inadequate facilities for cleaning complicate the process. Some objects have to be removed from display cases to be cleaned.	Minor local deformation or patchy colour changes of the surface in most sensitive and inaccessible areas. Mainly relevant for sleds and part of the wagon.	NB Bygdøy, Bjørvika and RE Bygdøy - Improved accessibility in display cases leads to simplified access simplifies cleaning reduces likelihood of damage. Improved ventilation leads to less frequent need for cleaning EX and RE Bygdøy lack adequate facilities for cleaning of objects complicating the cleaning process and increasing risk of unwanted events.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
R-0094	Direct physical forces	Vibrations on museum objects from outside infrastructure	Road, railway, tram construction work on adjacent buildings. EB Bjørvika - This is the centre of Oslo - Significant infrastructure projects are on-going and must be expected to be on-going in the area in the future. Despite the COWI report conclusions there is still uncertainty regarding ability to adequately install vibration absorbers to reduce the potential vibration to an acceptable level. Railroad tracks very close to the building.	Ref Vibration risk. Alum preserved object are most sensitive		PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0096	Direct physical forces	Lack of stabilization leads to Excessive tilting of alum preserved object during transport	Excessive tilting of object when exiting building or loading onto transport unit Excessive tilting of object due to inclinations on transport route Lack of or failure of stabilization mechanism (gyro) Excessive speed during moving doesn't give adequate time to adjust tilting Tilting/movement inside the transport frame.	Ref 26 but higher consequence and slightly lower probability Loosening of joints, some small fragments may come lose. Not expected to lose large fragments. Repairable damage and may have significant effects on the object. Both the breaking off and the impact of landing of fragments may cause damage that may have significant effect.	Lifting object onto transport vehicle. The lifting must be tested and practised with a simulated load. NB Bygdøy: Some sort of levelling platform (e.g. hoover craft platform) on prepared route for objects that are moved between existing and new building. NB Bjørvika: Vehicle with hydraulic levelling platform used to level out gradient on transport route, (e.g. down to Dronningen, onto and off barge) and into new building. Entering the new building is done in reverse of the process of leaving existing building.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH
R-0099	Fire	Flammable objects are placed too close to heat source and catch fire damaging objects on display	Smoking Damage to wiring in electrical appliances ignite fire (lighting, equipment). Heaters	Destroys, scorches, or deposits smoke on all types of artefacts, particularly those that contain organic materials Physical impact from CO2 from fire extinguisher. Biological degradation	Fire detectors and fire extinguishers in place. NB improved fire detection and extinguishing equipment.	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH	PH LPH BI LBI CH LCH

Moving of historical Viking Ships from Bygdøy
Appendix 7– Risk matrices and list of assessed risks

ID	Hazard	Name	Cause	Consequence	Comment	0 - EX Bygdøy	1 - NB Bygdøy	2 - RE Bygdøy	3 - NB Bjørvika
				because of soaking. Chemical damage due to smoke deposits and soaking.					