Maintenance in historic buildings in Belgium and Portugal

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Dissertation to obtain the Master Science Degree in

Civil Engineering

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For many buildings maintenance is an invisible part of the building industry, nevertheless is it an essential management strategy to protect a building in good working condition and ensure a large life cycle. The purpose of maintenance is to extend the service life of a building and its elements with as little effort as possible. An effective maintenance plan will reduce costs regarding maintenance; major expensive repairs are avoided or delayed when possible. Because the condition of the building is stable when maintenance is performed, the value of the building will be improved. This is especially important when talking about a building with historic and/or cultural value. Worldwide organizations have been founded to help the building owners and raise awareness of the importance of good maintenance. In Belgium the organization 'Monument Watch Flanders' has been established to help and advice the heritage owners. Annual inspections are performed, recommendations are given and if desired maintenance plans can be made. This way the organization wants to put the importance of preventive maintenance in the spotlights.

In this master dissertation, the maintenance approach used in Belgium and Portugal are compared. The proposed methodology is used on four case studies (three former cloisters in Belgium and one monastery in Portugal) for which maintenance plans have been previously established. These plans are compared and discussed in terms of maintenance activities, resources, elements in need of maintenance and costs. It can be noted that the Belgian organization Monument Watch has a lot of experience and makes more effective maintenance plans. The Portuguese maintenance plan, which is the result of a PhD thesis contains a lot of interesting things that are missing in the Belgium. However the plan is not put to practice which makes it less effective than the Belgian maintenance plan and approach.

Keywords: Maintenance, Maintenance planning, Heritage, Conservation, Monument Watch
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# ABBREVIATIONS

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<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>AFNOR</td>
<td>French national organization for standardization (Association Française de Normalization)</td>
</tr>
<tr>
<td>BS</td>
<td>British Standards</td>
</tr>
<tr>
<td>CEN/TC</td>
<td>European Committee for Standardization / Technical Committee</td>
</tr>
<tr>
<td>CIOB</td>
<td>Chartered Institute of Building</td>
</tr>
<tr>
<td>EN</td>
<td>European Standards</td>
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<td>HEREIN</td>
<td>European Heritage Network</td>
</tr>
<tr>
<td>ICOMOS</td>
<td>International Councils on Monuments and Sites</td>
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<tr>
<td>ISO</td>
<td>International Organization for standardization</td>
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<tr>
<td>MOH</td>
<td>Maintain our Heritage</td>
</tr>
<tr>
<td>MHS</td>
<td>Monitoring Heritage System</td>
</tr>
<tr>
<td>NBN</td>
<td>Belgian normalization institute</td>
</tr>
<tr>
<td>NF</td>
<td>Norme Française</td>
</tr>
<tr>
<td>PRECOM³OS</td>
<td>Preventive Conservation, Monitoring and Maintenance of Monuments and Sites</td>
</tr>
<tr>
<td>RICS</td>
<td>Royal Institute of Building</td>
</tr>
<tr>
<td>RLICC</td>
<td>Raymond Lemaire International Center for Conservation</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
</tr>
<tr>
<td>WTCB</td>
<td>Belgian research Institute (Wetenschappelijk en technisch centrum voor het bouwbedrijf)</td>
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1 INTRODUCTION

This first chapter is an introduction to the dissertation submitted in partial fulfillment of the requirements for the Degree of Master of Applied Engineering Construction at the University of Ghent, UGENT and Instituto Superior Técnico LISBON as part of the Erasmus exchange program. This dissertation is the result of a research project focusing on maintenance of historic buildings and maintenance planning in two countries: Belgium and Portugal.

1.1 Personal motivation

Maintenance and the importance of maintenance are topics that are not getting the attention that they deserve and need. Especially when talking about historic buildings a good preventive maintenance strategy has many benefits regarding the physical appearance of the building, the maintenance costs and the overall condition of the building. In Belgium the organization Monument Watch helps heritage owners taking care of their buildings. This organization creates maintenance plans, performs annual inspections and gives overall advice and recommendations regarding maintenance and safety measures.

Because of the lack of maintenance planning in historic buildings in Portugal and the more reactive way of maintenance it seemed very interesting to me to compare Belgium with Portugal regarding maintenance. Being a Belgian student that took the chance of finishing her master degree in Portugal as part of the Erasmus program I had the ideal background to compare and study the maintenance approach in both countries. This added to my personal interest in historic buildings and history, the topic of this master dissertation was found.

1.2 Scope and goals

Maintenance of buildings becomes more and more important, it helps saving the cultural heritage and it maintains or improves the comfort of the users. In search of a more effective and efficient organization of the maintenance planning that can be used in Europe, a comparison of the approaches in Belgium and Portugal can be a good starting point. For this comparison four case studies are used to see how and if the theory is put to practice. Because of the success of the organization Monument Watch, their approach will be studied thoroughly and compared to the Portuguese approach.
In this dissertation the following question will be answered:

- What are the differences and similarities in the approach and way of maintenance planning in both countries?
- What are the specific elements in the maintenance plan of both countries that contributes to an effective and efficient building maintenance and that could be the ingredients for a better maintenance strategy and maintenance plan that can be used in Europe in the future?
- Could an organization like ‘Monument Watch’ work in Portugal and why or why not?

1.3 Organization

The first chapter is an introduction of this master dissertation. It explains the scope, the goals and the organization of the research.

The second chapter, state of the art, will take a closer look at the most important definitions and theories on this topic that can be found in previous research projects, books and other literature works. It will also take a look at the way Europe deals with building maintenance, the norms and standards that are created to help the building owners, the legislation and the organizations that have been founded with the aim of promoting maintenance in historic buildings.

The methodology that will be used for the research project is explained in the third chapter. This master dissertation includes a comparison between the maintenance in Belgium and Portugal. For this comparison the maintenance plans of four case studies (three buildings in Belgium and one in Portugal) are used. By studying the three Belgian case studies, the approach of Monument Watch can be tested on the building in Portugal. This way the feasibility of the organization can be discussed.

In the fourth chapter the results of the comparison will be written down and discussed. This comparison happens on three different aspects of maintenance. At the end of this chapter a general comparison will be made.

The final conclusion of this master dissertation can be found in chapter five.

At the end of this master dissertation the bibliography is included which collects all the references used for this research project.

In the appendices a translated example of the maintenance plans in both countries can be found. In a third appendix the general comparison sheet can be found. This sheet contains a summary of the comparison, shown in a visual way.
2 STATE OF THE ART

Maintenance and maintenance planning are often forgotten about in the construction world. It has been described as the ‘Cinderella’ of the building industry, with little glamour, unlikely to attract much attention and frequently regarded as unproductive. (Seeley I.H., 1976) A lot has changed since Seeley used that appellation and the interest in maintenance began to grow.

This chapter takes a closer look at the definition of maintenance and its importance, it explains the terms service life and service life planning. It also discusses the regulations and norms in the world and will focus more on Belgium and Portugal. Several organization, both international and national have been founded to help maintain the cultural heritage.

To have a good an effective maintenance it is important to make a maintenance plan. This chapter will give more information about the elements of a maintenance plan.

2.1 Definition and importance of maintenance

No building is maintenance-free, every structure, heritage or new, is in need of some maintenance to limit deterioration. Every building is exposed to the elements of nature and to the users of the building which causes the building materials to wear down after a certain amount of time. To extend the life of the building and its components a set of maintenance related requirements can be found in the NBN EN 15531 (2011):

- The need to maintain property value of the building over time;
- The possibility that the property may undergo a significant change in its intended use during its service life;
- The number of persons responsible for maintenance and the different type of responsibility (owner, administrator, tenant, user, ...);
- Its long service life (decades)

This European Norm, adapted by the Belgian bureau for standardization also mentions that it is difficult to predict with any degree of precision the service life of each component under these conditions. Budgeting for maintenance and especially the scheduling of maintenance interventions requires the availability and the analysis of feedback data obtained from maintenance activities.
Maintenance is defined by ISO 15686.1 (2011) as ‘the combination of all technical and associated administrative actions during the service life to retain a building or its parts in a state in which it can perform its required functions.’

Another slightly different definition can be found in the BS 3811 :1993 where maintenance is defined as ‘the combination of all technical and associated administrative actions intended to retain an asset in, or bring it to a state in which it can perform its required function.’

This last definition implies that there are two processes in maintenance that have to be considered; ‘retaining’ which is the work carried out in anticipation of failure and ‘restoring’ which is the work needed after failure.

Maintenance can be subdivided into planned and unplanned maintenance as illustrated on Figure 2.1 (Council on training in Architectural Conservation, 2015)

- **Unplanned maintenance or corrective/emergency maintenance**
  A response to problems that have not been identified in the past or could not have been foreseen. It is work that must be done immediately for health, safety or security reasons or that may result in the rapid deterioration of the building structure if not done.
  e.g. roof repairs after a storm or repairing broken glass. (Heritage Resources Branch, 2014)
Planned maintenance

Work to prevent problems which can happen predictably within the life of a building. This type of maintenance can be further divided as follows:

- **Preventive maintenance**
  
  This is the process of using a strategic plan to replace (or repair/stabilize) things before they have failed. (Menzies G. F., 2000)
  
  This type of maintenance can be further split into:
  
  - **Schedule based maintenance**
    
    Maintenance is performed based upon predefined scheduled intervals.
  
  - **Condition based maintenance**
    
    A maintenance strategy that monitors the actual condition of the asset to decide which maintenance actions need to be done. The work is only being done after a decrease in the condition of the asset that has been observed.
    
    This type of maintenance is not often used for buildings. (Maintenance assistant, 2016)

- **Corrective maintenance**

  This planned version is most likely the result of a run-to-failure maintenance plan; assets are deliberately allowed to operate until they break down, at which point reactive maintenance is performed. The difference with unplanned corrective maintenance is that the failure is foreseen and so maintenance can be planned.

  e.g. light bulb, the bulb is allowed to run until it fails. At this time, the plan to fix the asset is carried out. A new light bulb is obtained from stocks and replaced at a convenient time (maintenance assistant, 2016)

It is advisable to have a planned-preventive maintenance strategy, the advantages of this maintenance type over corrective maintenance are as follows: (Shohet I.M. & Leibovich S., 2002)

- Since maintenance is pre-planned, it can be carried out in a manner most convenient for the users.
- It assures conservation of the good repair and completeness of the building at all times, practically without its operating under conditions of failure.
- Reduction of the cost of maintenance by preventing “concatenations of mishaps”
- Improvement of the convenience and the safety of the users of the building.
- Savings in the cost of works as a result of the ability to control the time of execution.
Shohet I.M. and Leibovich S. (2002) also remark some disadvantages to this method:

- Many components are replaced when they are still able to serve the users’ purposes for further period of time (the replacement of components does not necessarily conform to their actual service life). The result of this approach is over-maintenance.
- Preventive maintenance requires available manpower in full employment.

2.1.1 Importance of maintenance

The benefits of a good maintenance strategy can be short term of long term and can be reflected in the areas of physical, financial or human resources.

First of all will maintenance preserve the physical characteristics of a building and its services, this is very important for buildings with a touristic or cultural value. Other advantages are fewer breakdowns and lower future maintenance costs. The improved condition of the building gives a positive effect to the users resulting in lower staff turnover, better customer relations and public image.

When talking about heritage it is obvious that whenever possible preserving the original building elements is preferred to a replica. According to Forster A.M. and Kayan B. (2009) maintenance and retaining historic heritage leads to the retention of cultural significance. To ensure that a building maintains its integrity, it is critical to have a good maintenance strategy. The purpose of maintenance is to ensure longevity, reduce costs and improve value. (Heritage Resources Branch, 2014) The most appropriate way to do this is to have maintenance on a minimal intervention basis. Forster A.M. and Kayan B. (2009) mention that the aim of this minimal intervention strategy is to maintain the building without damaging the building character. It tries to avoid unsympathetic alteration of important features or prevention of unnecessary disruption or destruction of the fabric that gives the significance of the building.

It is important that buildings continue to be properly maintained to ensure that they will function as efficiently and effectively as possible. The deterioration of buildings due to the lack of maintenance could lead to future major expensive repairs. This effect is shown on Figure 2.2 where the repair costs are shown in time. This graph shows that by having a preventive maintenance strategy the total costs are suggested to be about two thirds lower than when no maintenance has been done and major repairs are needed to keep the building in a good condition.
Figure 2.2: Comparison of the repair costs and preventive maintenance costs (Van Nostrand R. 1991)

According to Feilden B. (2003) minimal-intervention can only work when regular inspections are performed. This raises the question about the costs associated with survey and inspection. Is minimal intervention still the best cost-efficient way of maintaining a building when so many inspections are needed?

Preventive maintenance is also a very sustainable way of dealing with the process of wearing down of materials. Figure 2.3 shows the impact of programmed maintenance for a construction element. When no maintenance has been done, the element will need replacement in ‘year x’. This time period can be doubled when preventive maintenance is the strategy that is used, more maintenance is needed but the replacement is postponed by many years. Annual overhaul is a strategy that can be found between no maintenance an preventive maintenance and can be a good solution if the company is not capable of having a preventive maintenance.

Figure 2.3: Impact of preventive maintenance (Ankit N. 2015)
The motivation for owners to undertake maintenance is lacking in general and could be better. Most owners wish to protect and maintain the function and appearance of the building but unfortunately they tend to take a short-term approach to maintenance. The most important reason for this is the absence of understanding the benefits of regular minor interventions. Many owners have an ‘if it is not broke, why fix it?’ mentality. (Dann N. & Cantell T., 2007)

When looking at historic building owners, ‘Monument Watch The Netherlands’ (2000) found out that most building owners did not know when and how to make the necessary repairs. They often believed that repair and replacement was the best course of action to enable the retention of cultural significance.

Current drivers for maintenance tend to focus on reducing cost and inconvenient repairs rather than to fulfil conservation objectives. According to Maintain our Heritage (2004), there is a lack of engagement between the owners and the people trying to satisfy the conservation principles, one of which is regular maintenance. It is clear that the public needs better and more advice on the principles of building conservation philosophy that underpins the practical aspirations of heritage bodies.

2.2 Service life and service life planning

Some other important definitions regarding maintenance and maintenance planning are ‘service life’ and ‘service life planning’. According to the ISO 15686.1 (2000) is service life ‘the period of time after installation during which a building or its parts meet or exceed the performance requirements.’ Service life planning on the other hand is defined as ‘the preparation of the brief and design for the building and its parts to achieve the desired design life, for example in order to reduce the costs of the building ownership and facilitate maintenance and refurbishment.’

The objective of service life planning is to assure that the estimated service life of the building or component will be as long as its design life. The length of the service life cannot be known exactly in advance. Therefore the main goal of service life planning is to make an appropriately reliable forecast of the service life using available data. The output of this planning will be a series of predicted service lives of components, and a projection of maintenance and replacement needs and timings. This can be the start of the maintenance planning. (ISO 15686.1, 2000)

In terms of the physical building, the length of the service lives of the envelope, components, assemblies and materials is determined by two key factors. The first is the extent to which the differential service lives of the various components are harmonized and the second relates to a host of agents that can impact on their durability.
Service life planning ensures that components with shorter service lives can be easily replaced. The severity and frequency of degradation agents (like wind, traffic vibration, the action of water, ...) have a bearing on the durability of the building envelope, its components, assemblies and materials and will have an effect on the service life.

For very long design lives (e.g. for important buildings) the level of maintenance and ease with which it can occur is likely to significantly influence the service life. If the service life of an essential component is less than the design life of the building, it should be replaceable or maintainable. (Lambie B., 2012)

2.2.1 Service life forecasting methods

ISO 15686.1 (2000) makes a reference of two methods used to forecast a building’s service life. One is based upon knowledge of the predicted lives for all the materials, components and assemblies forming the building and the other method is based on applying a series of modification factors to reference service lives.

**Predicted exposure evaluation method**

According to the ISO 15686.1 (2000), a forecast service life is referred to as ‘the predicted service life’ if it is based on procedures which usually involve tests to determine length of service life for a specific material, component or assembly.

If the conditions are known, relevant and complete, at least for the most important degradation agents, a service life prediction derived from exposure and performance evaluation is possible, but accessing a comprehensive and reliable data set is problematic.

**Factor method for estimating service life**

Rather than relying on the availability of empirical evidence, another approach makes use of a reference service life that can be adjusted to reflect local, project-specific factors. This is referred to as the ‘estimated service life’.

This method allows a series of modifying factors to be applied to an estimation of the service life to be made for a particular component.

Factors less than 1 reduce the estimated service life and factors greater than 1 increase it.
ESLC = RSLC x factor A x factor B x factor C x ...

With ESLC is the estimated service life of the component and RSLC is the reference service life of the building.

This ISO Factor method of estimating service life is based on the following seven factors: A. quality of materials, B. design level of a component’s or an assembly’s installation, C. installer skill level, D. indoor environment, E. outdoor environment, F. in-use condition and G. maintenance level.

To date, practical applications of this method have been rather limited and most of the cases published are described in theoretical studies that give examples of its use. This is because of the fact that those involved in the field are not familiar with the method and also because of the need for useful values for the factors. (Madrigal L., Lanzarote B. and Bretones J., 2015)

2.3 Maintenance practices, standards and regulations

In the European Union, the maintenance sector is marked by two important periods. The period after the Second World War saw the introduction of economic and durability principles that influenced the decisions of demolition or conservation of buildings. Meanwhile an enormous building park was erected, constituted by housing buildings and facilities of a public, commercial or industrial nature.

On a more stable economic phase with stagnation in population growth, the construction industry embraced maintenance and rehabilitation to improve the habitability demands of an important number of existing buildings with a dubious technical quality. (Silva J. & Falorca J., 2009)

The construction world has attempted to incorporate sustainable development principles of improving the well-being of the current and future generations. The first attempt to establish a coherent and logically defensible philosophy for building conservation was in the Society for the Protection of Ancient Buildings’ Manifesto of 1877. This Manifesto consists principally of a plea to put ‘Protection in place of Restoration’. The last two paragraphs of this document mention a philosophy of care. This was the starting point for many following policy statements. (Gillon J., 1996)

The Athens Conference of 1931, organized by the International Museums Office, established the basic principles for an international code of practice for conservation. The Second International Congress of Architects and Technicians of Historic Monuments, which met in Venice in 1964, approved the text of an International Charter for the Conservation of Monuments and Sites (The Venice Charter) superseding the Athens Charter. This new charter stresses the importance of setting, respect for original fabric, precise documentation of intervention, the importance of contributions from all periods to the building and the maintenance of historic buildings for a socially useful purpose.
The Charter outlines the basic tenets of what is now accepted to be an appropriate approach to dealing in philosophical terms with historic buildings. (Gillon J., 1996) It also states that it is essential to the conservation of monuments that they are maintained on a regular basis. (ICOMOS, 1996)

European Architectural Heritage Year, 1975, a Council of Europe initiative, was probably the catalyst for thinking about how historic buildings values not only for their recollection of the past but also, and perhaps principally, for their contribution to the present and future, could be sustained in use. International statements of best professional practice, particularly The Venice Charter (1964), were still concerned primarily with monuments whose exceptional significance was evident at national, and often international, level and where ongoing use was desirable, but not essential, to survive. (Drury P., 2012)

The idea of ‘conservation planning’ was pioneered by James Semple Kerr in Australia and underpinned (with the Venice Charter) the Burra Charter, which was adopted by ICOMOS Australia in 1979. This new charter defines conservation as ‘all of the processes of looking after a place so as to retain cultural significance’. This cultural significance of a place is embodied in its fabric, the setting and its contents. (Dann N., Worthing D. & Bond S., 1999) While The Venice Charter and its precursors prescribed what was necessary to protect a relatively narrow range of heritage values, the Burra Charter sets out a process for identifying the values people attach to places as the basis of managing change in ways that seek to retain ‘all aspects of (their) cultural significance’. The heritage values of places were seen as often both multiple and mutable. Heritage practitioners therefore needed to become advocates and enables as well as conservators, particularly in relation to the values attached to places by the communities that identify with them. (Drury P., 2012)

To help the building owners with creating an efficient and effective maintenance strategy several norms and standards were created.

**ISO 6707.1 (2014): Building and civil engineering works, vocabulary, part 1: general terms.** This norm created by the International Organization for Standardization, comprises fundamental concepts, which can be the starting point for other, more specific, definitions used in several areas of construction and frequently used in standards, regulations and contracts.

**NF 60-010 (1994),** created by AFNOR, the French national organization for standardization, defines the five levels of maintenance associated with the degree of intervention. Level one defines simple settings, where no dismantling or deconstruction is needed. Level five demands renovation, reconstruction and other major repairs.
BS ISO 15686.1 (2011): Buildings and constructed assets – service life planning part 1: general principles. This is an international norm adapted as a British Standard with identifies and establishes general principles for service life planning and a systematic framework for undertaking service life planning or a planned building or construction work throughout its life cycle (or remaining life cycle for existing buildings or construction works).

NBN EN 15331 (2011): Criteria for design, management and control of maintenance services for buildings. This might be the most important standard regarding building maintenance. The scope of this European Standard specifies the criteria and the general methods that can be used in the planning, management and control of maintenance in buildings and their surrounding area according to the applicable legal requirements, objectives of the owners and users and the required quality of maintenance. EN 13306 (2010): maintenance – maintenance terminology and EN 13460 (2009): maintenance – documents for maintenance, are two documents that give more background information about maintenance in general and are used as references in the EN 15331 standard.

When talking about heritage the general norm is: NBN EN 15898 (2011): conservation of cultural property – main general terms and definitions. It is a part of a series of standards being developed by CEN/TC 346. It provides terms and their definitions for a set of general concepts which are widely used by those working in the field of conservation of cultural heritage. Its purpose is to bring greater understanding and encourage collaboration amongst those who have responsibility for or an interest in cultural heritage.

Another standard that can be useful when dealing with heritage is NBN EN 16096 (2012): Conservation of cultural property – condition survey and report of built heritage. This European Standard provides guidelines for a condition survey of built cultural heritage. It stated how the condition of the heritage should be assessed, documented, recorded and reported on. It encompasses evaluation of the condition of a building or other structure mainly by visual observation.

This standard may be applied in order to:

- Identify maintenance measures and the need for further investigation and diagnostics of damage;
- Define procurement need and the requirement for detailed specification;
- Provide a unified method to obtain comparative data, when carrying out a condition survey for a group of buildings or a region.
2.3.1 Belgium

Regular maintenance in buildings is not obligated by law. The owner of a building is responsible for the needed works and the building condition. Only for technical installations an annual or biennial maintenance with inspection is mandatory.

In 2012, the building regulations became stricter and more demanding for safe maintenance for new constructions. Therefore a handy checklist has been created and has been added to the application for an environmental building permit. This checklist lists all the building components that are considered to be dangerous or hard to reach when doing maintenance works. With every component safety measures are listed and the owner has to tick off which measures are present in the building and whether they meet the possibilities regarding the specifications of the building and its environment.

Making or having a maintenance plan is not mandatory but is recommended for shard buildings such as apartments or big office buildings where the maintenance of the shared components is the responsibility of all users. One person, the syndic, has the main responsibility and should make the maintenance plan. Research has shown that very few maintenance plans have been made. (Vlaanderen.be, 2016)

In case of a listed heritage building, which means that the building has a special architectural and/or historic value, there is some legislation regarding conservation and maintenance. The main idea of conservation policy is that the responsibility of a protected building or landscape lays with the owner. The government supports and monitors the owners with advice, subsidies and legislation. Legal protection of buildings with a value exists in Belgium since the 20th century. The first law, in 1931, concerned the protection of monuments and landscapes when a building is protected as a monument, the owner cannot change the appearance of the building. The Flemish agency for immovable heritage implements this policy and aims to conduct research, composes inventories, protect and finally raise awareness regarding the heritage. The largest inventory for built heritage contains over 80 000 items or relics. This list has been started in the 1970’s and is since 2009 used as a policy instrument; this means that there are legal consequences for properties listed on the inventory. (De Roey N., 2013)
2.3.2 Portugal

The Second World War did not affect Portugal in a big manner, the evolution of the building maintenance sector has been the result of other effects. Mainly the industrialization process that started in the 1960s combined with the implementation of construction politics for social dwellings after the revolution of 1974. Over the past years, construction development has basically been sustained through investments in equipment and infrastructure with public interests; expansions of the urban areas and in the materialization of the Expo ’98 and Euro Football Championship 2004 projects. This realization of new projects was not accompanied by recovering the oldest buildings in the city centers. (Silva J. & Falorca J., 2009)

The maintenance of buildings in Portugal is based on an empirical approach because of three reasons. First of all is the budget in most cases insufficient for an intensive and systematic maintenance. The owners of the buildings have small knowledge of the maintenance benefits and the lack of technical models and support tools to help planning actions is causing the experimental based approach. (Silva J. & Falorca J., 2009)

Some other reason for the lack of a good maintenance approach is the absence of legislation requiring long-term consideration of maintenance, as for example, the Italian law 109/94 which requires the development of a maintenance plan for every public work’s design. These plans provide the scheduled maintenance activities and economic value. (Freitas V., 2013)

The new Portuguese building regulation, still under discussion, introduces requirements for durability and maintenance purposes. According to it, the development of an inspection and maintenance manual is mandatory as part of the execution project. This new regulation also introduces three definitions; building service life, component service life and service life required by the owner/promoter. The building service life corresponds to the period during which the structure shows no degradation of materials. The building component’s service life must be set by the manufacturer. The building’s service life is a requirement set by the owner/promoter and, when it is not defined, it is considered, by default, 50 years. (Freitas V., 2013)

Legislation relating to safety and health on temporary or mobile construction sites forces the owner to provide a building technical compilation that includes all the necessary information to take into account it the use, conservation and maintenance activities but also taking into considerations the safety and health of those who deliver them.
Although this legislation was published in 2003, the preparation of the building technical compilation is far from current practice. The existence of other priorities related with lack of time, meeting deadlines already short, the intervention of many actors with various scattered information, are presented as an obstacle to the development of this important document.

Nowadays there are more reasons for an increase in the attention to building operation and maintenance phases. There is a very sharp decrease in the construction of new buildings, especially for housing purposes. In the public sector, the economic considerations associated with the management of property assets, are on the agenda in face of the present severe financial constraints. The public owners have been aware of the costs associated with the working, operational and maintenance activities. Since it is economically important to the building total cost, the maintenance management cannot be done in an improvised and casual way. It is necessary to start adopting practices aiming at a sustainable approach by rationalizing and optimizing the available resources through implementation of integrated and cost-effective solutions, allowing an acceptable performance of buildings throughout its life cycle. (Freitas V., 2013)

2.4 Maintenance and conservation in heritage buildings

Putting a definition on ‘heritage’ is not an easy job, in common parlance heritage is used when referring to particular examples of built history environment or culturally-influenced landscapes. According to the Oxford Dictionary heritage are ‘the valued objects and qualities such as historic buildings and cultural traditions that have been passed down from previous generations.’

There is a difference between maintenance in current and historic buildings. The essential aim of maintenance in non-historic buildings is to retain a continuity of function. When dealing with a historic building, the attention is not only on the continuity of function, it is the fabric itself that is important because of its cultural significance. (Dann N., Worthing D. & Bond S., 1999)

2.4.1 Conservation practice

Kerr J.S. (1996) states that maintenance is the single most important conservation process. Whether the place is architectural, mechanical or botanical. Prevention is better than cure. The practice of conservation varies between countries and cultures around the world. The making of decisions is rarely straightforward.
The decision should be based on many factors, some of them identified in the condition survey, others determined by significance, others deriving from the context and current use or following from discoveries made during the work. Dann N., Worthing D. and Bond S. (1999) use the commonly used expression ‘as little as necessary, as much as possible’ when talking about conserving a historic building. This expression adds another dimension to the debate about planned-preventive maintenance, planned and reactive maintenance. According to these authors it is generally agreed that maintenance is a key process in the care of historic buildings. Yet, despite a number of significant and distinctive responsibilities imposed on the owners, there has been little published discussion regarding the differences in approach that should be taken towards their maintenance management.

Laws and regulations in some CEN member countries may contain specific rules relating to professional qualification and/or methods of control for interventions. Furthermore, various international and national organizations have been developing professional qualifications, standards and guidelines which increasingly help to identify those who are equipped to contribute to conservation decisions and to implement them. (EN 15898, 2011)

According to the EN 15898 (2011) standard ‘conservation’ is defined as: ‘the measures and actions aimed at safeguarding cultural heritage while respecting its significance, including its accessibility to present and future generations.’

NOTE: Conservation included preventive conservation, remedial conservation and restoration. Preventive conservation can be seen as the measures and actions aimed at avoiding or minimizing future damage, deterioration and loss and, consequently, invasive intervention. Remedial conservation are the actions applied directly to an object to arrest deterioration and/or to limit damage. Restoration are the actors applied to a stable or stabilized object aimed at facilitating its appreciation, understanding and/or use, while respecting its significance and the materials and techniques used. In some countries the term ‘restoration’ may be taken to mean the whole conservation project, either to maintain some current or to establish some former state.

Knowledge and understanding of the material evidence of built cultural heritage and the information on its current state is important because it helps to specify the measures necessary to preserve structures in an appropriate condition and ensure that the maintenance required to keep them at this level is well defined.

As mentioned before, the NBN EN 16096 standard talks about a condition survey. This is a management tool and it is the first step in a process to develop plans and measures needed to keep the heritage in a stable well-maintained condition.
It acts as the basis for recommending preventive conservation, maintenance and immediate repairs and for a more detailed planning and consideration for further measures or studies. When damage is detected and the causes are not evident, it will be necessary to have a more detailed inspection or diagnosis outside this standard in order to execute further remedial measures of an appropriate quality.

In 2010 Stefano della Torre identified that preventive conservation should be based on three levels of prevention. He used medicine as an inspiration source for this theory. These levels are:

1. **Primary prevention**: trying to avoid the causes for the unwanted effect.
2. **Secondary prevention**: monitoring which allows an early detection of the symptoms of the unwanted effects.
3. **Tertiary prevention**: avoiding the further spread of the unwanted effect or the generation of new unwanted effects.

He has clarified that primary intervention starts with assuring the proper use of the building, besides other types of preventive measures as assuring good air quality and good state of maintenance. It should also include a good integration in society to avoid vandalism.

### 2.4.2 Conservation plans

Maintenance for historic buildings has received more attention with the introduction and promotion of conservation plans. These were introduced in the late 1990s (Dann N. & Cantell T., 2007) and have as primary aim highlighting the significance of a building or place via an assessment of analysis of conservation needs. This is determined by a condition survey, which forms the basis for a routing building maintenance schedule. (Forster A.M. & Kayan B., 2009)

Clark (2011) puts focus on the idea that ‘the sensitive repair and maintenance of an historic building and its landscape is not just a matter of specifying traditional materials and techniques. It requires an appreciation of why the site is significant, how this significance is embodied in the fabric and what impact potential repairs might have on it. This statement shows that repair works may diminish the significance of a building is inadequately or excitedly undertaken. This has led to an alternative approach, proposed by several authors (Kerr, 2000; Miele, 2005; Gardner, 2007). This new strategy puts condition survey on the basis of early identification of defects and thereby reduce the need for physical interventions. However, critics of conservation plan question if these maintenance regimes are truly implemented. Cynics could see these reports as a way to get funding because after a project has been completed, there is no ability to check that the suggested works are regularly undertaken. (Forster A.M. & Kayan B., 2009)
Forster A.M. & Kayan B (2009) mention that there are some problems that have to be remarked regarding maintenance for historic buildings. It is clear that maintenance is a good strategy for conservation but it is not included in many national policies. Maintenance policy is in general poorly integrated, with a lack of leadership and/or deviations from procedural systems being a major problem. National policies that are supporting maintenance have been implemented in Denmark and the Netherlands with great success.

2.4.3 Organizations

Several organizations both international and national have been founded to help maintain the cultural heritage and to raise awareness. Some of the most known or successful are mentioned below.

UNESCO World Heritage Committee

The most known organization is probably UNESCO which stands for United Nations Educational, Scientific and Cultural Organization. This organization was created for more than half a century ago, with the mission to build the defenses of peace in the minds of men. As a part of this organization the World Heritage Committee has been founded which chooses the sites to be listed as UNESCO World Heritage Sites. The Committee is responsible for the implementation of the World Heritage Convention, defines the use of the World Heritage Fund and allocated financial assistance upon requests from States Parties. It has the final say on whether a property is inscribed on the World Heritage List. It examines reports on the state of conservation of inscribed properties and asks the States Parties to take action when properties are being poorly managed. It also decides on the inscription or deletion of properties on the List of World Heritage in Danger. (whc.unesco.org, 2016)

European Heritage Network (HEREIN)

To obtain and maintain the heritage in Europe, the European council took the lead in making a plan to manage the heritage through conventions, declarations, resolutions and recommendations. On the website of the European Heritage Network (HEREIN) all those documents can be found.

ICOMOS

A very important organization that deals with conservation and protection of cultural heritage places is ICOMOS (International Council on Monuments and Sites). This organization is the only global non-governmental organization of this kind, which is dedicated to promoting the application of theory, methodology and scientific techniques to the conservation of the architectural and archeological heritage. Their work is based on the principles enshrined in the 1964 International Charter on the Conservation and Restoration of Monuments and Sites. (The Venice Charter)
**PRECOM³OS – UNESCO Chair and network**

The UNESCO chair on preventive conservation, monitoring and maintenance of monuments and sites has been established at the Raymond Lemaire International Center for Conservation (RLICC) at K.U Leuven in Belgium in collaboration with Monument Watch Flanders (Monumentenwacht vlaanderen) and the University of Cuenca (Ecuador). They named this collaboration PRECOM³OS, which is the abbreviation of Preventive Conservation, Monitoring and Maintenance of Monuments and Sites.

It aims at identifying research and educational activities in the field of preventive conservation, maintenance and monitoring of monuments and sites, so as to contribute to:

1. Identifying the particularities of preservation policies and practices;
2. Developing new appropriate tools and techniques to improve preventive preservation strategies;
3. Developing legal frameworks, policies and exemplary field applications considering the variety of cultural and social contexts. (Precomos.org)

On a national level there are a some organizations that are very successful, one of the most known and the organization that started the heritage interest is Monument Watch (Monumentenwacht), founded in the Netherlands and has been an example for other national organizations.

**Monument Watch (Monumentenwacht) – The Netherlands/Belgium**

Monument Watch is originally a Dutch organization founded in 1973 by two individuals on request of a group of monument owners and was supported by the Ministry of Culture. Listed building owners subscribe to the service and pay a subsidized hourly rate for an inspection and subsequent prioritized maintenance plan. The basic services of the Dutch organization is independent of the conservation authorities and includes (Maintain our Heritage, 2003):

- An annual inspection of the external envelope, roof and the interior. For some smaller dwellings the inspection may occur less frequently, for example between 18 and 24 months. The inspectors also perform some ‘first aid repairs’ to items of a critical nature encountered during the inspection.
- A prioritized maintenance plan and advice to the owner/subscriber.

Monument watch has dealt with some criticism from the contractor’s side, saying that Monument Watch was stealing their job. This criticism fade away faster than it arose, the watchers main and only duty was and is to inspect the buildings, they do not intervene.
By spotting all the work that needs to be done they steered activity in the sector, giving the contractors more work. (Lipovec N. & Van Balen K., 2008)

The success of the Dutch organization influenced the Flemish part of Belgium to do the same. In 1991 “Monumentenwacht Vlaanderen vzw” was founded on the initiative of the Association of Flemish provinces, the King Baudouin Foundation and the foundation monument and landscape care. One year later, the provincial Monument Watch associations were founded. From its founding objective the organization focused on preventive action. Their mission is: “the association aims to contribute to the promotion of the cultural heritage in Flanders, in particular by promoting their conservation. The emphasis will be on encouraging regular maintenance of heritage value”. (monumentenwacht.be)

In 1997 Monument Watch Flanders expanded their expertise to interior heritage and 11 years later, in 2008, they started to provide assistance to owners of maritime heritage. Only one year later archeological heritage was added to their services.

In 2011 the organization started establishing maintenance plans with cost estimations for their members. (Monumentenwacht.be)

In chapter four, three case studies of this organization are used for the comparison study of the maintenance plans in Belgium and Portugal.

**Raadvad Byginssyn – Denmark**

This Danish service, inspired by the Dutch organization Monument Watch, was established in 2000 as Raadvad’s Building Care. This initiative provides an annual inspection as part of a subscription service, principally of the exterior but also looking at basements and attics, performed by craftsmen with the necessary training. The report made during the inspection will identify the general condition of the building, together with a prioritized schedule of items requiring repair or other attention. It also provides a schedule of maintenance activities that should be undertaken at various intervals. This provision of service has many benefits for private owners of listed buildings, who are obliged to maintain their properties, although even with this obligation subsidies are generally focused on repairs rather than maintenance. (Maintain our Heritage, 2003)

**The Risk Map of cultural heritage – Italy**

The Risk map is not inspired by the Monument Watch concept, but it provides a comprehensive national catalogue of state-owned protected structures, which in this context includes buildings, conservation areas and landscapes.
This is a database of information on the condition of these structures and the environment in which they are located, and is available to both central and local administration with responsibility for cultural heritage. (Lazarus D. 2007)

In Italy the Merloni Law made it possible to put the theoretical maintenance approach into practice. This law stated that any building in receipt of public funding must have a strategic 10 year plan for maintenance in place before either capital or revenue funding is released. (Maintain our Heritage 2003)

**United Kingdom**

Within the UK, a pilot scheme was set up and operated in Bath by Maintain our Heritage to explore the potential for a Monument Watch-type approach in the UK. The ‘Bath Area Pilot’ was the first maintenance inspection scheme for historic buildings in the country. It demonstrated that such a scheme could be operated both technically and legally, but as yet there has been no widespread take-up of such a scheme elsewhere. (Lazarus D. 2007)

### 2.5 Maintenance planning

According to the NBN EN 15331 (2011) a maintenance plan is a ‘structured and documented set of tasks that includes the activities, procedures, resources and the time scale required to carry out maintenance. This definition can also be found in the EN 13306: 2010.

To have a long-term efficient maintenance plan it is important to think about it at the design phase if possible. By choosing the appropriate materials and proper construction, maintenance and repair demands can be less intensive. The design should incorporate suitable and safe access provisions for the inspection and maintenance work of all structures and equipment.

The most important reason to have a maintenance plan is that it is the most cost-effective way to maintain the value of a building. It is also very useful for annual budgeting, having a good and detailed maintenance plan can predict all costs. (NSW Heritage office, 2004)

Some other advantages of a maintenance plan are:

- The property is organized and maintained in a systematic rather than ad-hoc way;
- Building services can be monitored to assist their efficient use;
- The standard and presentation of the property can be maintained;
- Subjective decision making and emergency corrective maintenance are minimized. (NWS Heritage Office, 2004)
2.5.1 Collecting information about the building

When making a plan it is important to get as much information as possible about the current state of the building. The information should be available either for new constructions and restorations of buildings. When the needed information is not available this should be progressively acquired in a systematic manner and controlled.

This collection of information usually is separated in a preliminary data collection and a specific collection of information phase. (EN 15331, 2011)

During preliminary data collection the property to be maintained is to be identified and quantified; the date shall include all documents available and the following information, as a minimum: (EN 15331, 2011)

- Location;
- Gross volume and surface area, divided according to intended use (refer to standards if applicable);
- General characteristics of component parts (e.g. position inside the buildings, drawing, technical data sheets, instructions for maintenance issued by manufacturer, ...);
- Level of compliance with legal and regulatory requirements (objectives to be attained);
- Status of maintenance upgrading in accordance with pre-determined operational specifications;
- External constraints (monumental and environmental, servitudes (e.g. right of way) agreements with public bodies and bordering landowners, etc.);
- Legal and/or technical documents related to the installation, operation and maintenance of systems an equipment;
- Status of distribution systems and data concerning consumption (energy, water, etc.)
- Type and characteristics of services required to ensure operation of the building (premises for doorkeeper and cleaners, heating, etc.)

Collecting detailed information has to be done after the preliminary data collection. Some of these more detailed information can include data about maintenance activities already performed, repair or replacement costs for each component, information about critical construction solutions and many more. (EN 15331, 2011)
Some of the following tools can assist with the collecting information process;

When the building is defined as heritage the ‘Heritage study information sheet’ can be very useful. This information sheet is often prepared by the local council. It includes a description of the item, information on architectural style, historical significance and heritage listing and a photograph.

The maintenance log book records all maintenance work that has been carried out, including a description of the work, date of completion, estimated cost and actual cost, contractor and warranties. As this log book includes the actual price for the work that has been done, it is a valuable source for future budgeting.

2.5.2 Maintenance strategy/policy

In most practical guidance the requirement for clear aims and objectives is implicit, rather than explicit. The maintenance activity can be translated on two levels: a strategic level, describing the aims and objectives for the management of maintenance, and an operational level related to the procedures for implementation of maintenance. (Maintain our Heritage, 2003)

The Chartered Institute of Building (CIOB (1990)) and the Royal Institute of Chartered Surveyors (RICS (2000) suggested a list of questions that need to be answered to establish a strategy/set of appropriate policies in order to develop a maintenance plan:

What is required to be done?
Which items are the most important?
What are the legal requirements?
When can the work be done without loss of production or facilities or service?
How often should inspections, surveys, test and works be carried out?
Where is the money coming from?
What works are the most necessary, if funds may not cover all the work identified?

It is also important to specify the type of maintenance that is preferred; unplanned or planned maintenance.

Corrective or unplanned maintenance will be adopted when it is not economically feasible to adopt preventive measures and when the temporary decrease in service is acceptable, involving components that are not part of critical or safety systems. Emergency maintenance refers to unexpected malfunctions.
Planned maintenance is in most cases preferred above corrective maintenance. A preventive maintenance plan shall be developed for critical equipment. This should include all the collected data and manufacturers’ instructions. Long life components (with long life cycles) are to be checked periodically in accordance with a pre-established inspection plan; consequent interventions are typical of maintenance plans ‘condition based’. Maintenance plans should also consider maintenance activities that may be performed concurrently with the above mentioned activities, leading to financial savings and decreased maintenance time, stop in the operating conditions or problems for the users. (NBN CEN/TS 15331, 2006)

2.5.3 Maintenance activities

Maintenance activities can be separated according to type (repair, replacement, (re)painting and cleaning), part of the building component to which an activity applies, the specification of materials, the quantity of the work, the frequency of short cyclical preventive maintenance actions and the nature of the activity (preventive or corrective).

The performance of the building elements should be clear after executing maintenance. This is often not the case and technical managers are unsure about the performance of the elements after partial replacements, repairs and cleaning. When an integral replacement has been done the condition of the element will be as new. In case of partial replacement and repairs the condition gap before and after the activity is unsure. It depends on the solved defects at that particular moment of time. (Straub A. 2003) According to Hermans M. (1995) cleaning and repainting of surfaces will not influence the technical performance. The degradation will just process more gradually. However, the aesthetics of the surfaces improves.

Hermans M. (1995) mentions that although repair can remove some deterioration, it does not always lead to an ‘as new’ situation. The cleaning and repairing techniques used for a certain material can even cause deterioration of components due to aggressive action of detergents or mechanical damage resulting from the maintenance action itself.

When dealing with a heritage building there should be an understanding of the limits of specialist knowledge within the organization and appropriate outsourcing policies to ensure that the organization has the required skills available. The support staff should be suitably trained, particularly in use- and contractor-focused activities.
2.5.4 Preparing a program

The most effective way of planning is to make a maintenance plan on two levels:

- **Long term maintenance** up to and including the first painting cycle, which can extend to 50 years for a building with a slate roof or 100 years for a building with stonework.
- **Annual maintenance**: a schedule can be complied by assessing the annual inspection survey, day log book or diary and work carried over from the previous year. The daily response for carrying out urgent maintenance should be upgraded annually. (NSW Heritage Office, 2004)

2.5.5 Inspections

It is important to have regular inspections to have a good and effective maintenance. It is necessary to locate and define the possible defects and their symptoms. These defects occur in various forms and to different varieties in all types of buildings, irrespective of age. Below are some examples that all contribute to the occurrence of defects in buildings: (NSW Heritage office 2004)

- The large varieties of building materials used that may not be well congruent with one another;
- Construction techniques that may not be defect proof, inconsistent or substandard workmanship;
- Use of unsuitable construction details;
- Extreme site conditions undermining performance standards;
- Natural deterioration;
- Improper use of the completed building;
- ...

Regular inspections can help by identifying the building components and it will help seeing when an element might fail in the near future. Several manuals have been created to make the inspections easier, by following a checklist that lists the most common flaws in a construction element the inspection will be done quickly and correctly.

A system that can be used to monitor the building is designed by the Heritage conservation department of the Santa Maria La Real Foundation – Center for Romanesque Studies (FSMLR) in Spain. The Monitoring Heritage System (MHS) has been implemented and tested since 2005 in 21 heritage monuments in Spain. It has been developed to measure, record, evaluate and control various crucial and influential parameters in the conservation of heritage monuments in order to ensure sustainable management and optimal maintenance as well as all the elements housed within. It has two objectives: to implement a methodology of preventive conservation in heritage monuments and also
to generate a system and an infrastructure that permits sustainable and integral management. (Chiriac M., Basulto D. Lopez J.C., Castillo J & Collado A. 2013)

Several sensors (as seen on Figure 2.4) are placed at carefully chosen places where the desired parameter will be measured. The sensors send its information wireless to a ‘smart’ control center that will process all the information received from all the sensors. This leads to intelligent management and dynamic results.

![Figure 2.4: MHS - humidity sensor](Fundación Iberdrola España, 2005)

### 2.5.6 Preparing a budget

The annual budget needed for maintenance is in most cases a combination of the following three costs; (NSW, Heritage Office (2004))

- **Committed expenditure**, which includes task that are needed every year as a part of planned maintenance,
- **Variable expenditure**, which includes regular tasks within an overall program of planned maintenance that may not occur every year.
- **Managed expenditure**, which relates to unplanned maintenance, mainly emergency corrective maintenance.

The aim of a good maintenance planning is to reduce this last cost, the managed expenditure, because this is the highest cost. Finding all the materials and the contractors needed on a short time notice is more expensive.

An often forgotten important factor when calculating the budget is the accessibility of the components in need of maintenance. The time needed to actually approach the element is often forgotten but in some situations it can be longer than the time of the maintenance action. This time factor is related to some other factors; the position of the component in respect to other components (height above ground level and inclination or obstacles preventing easy access), the presence of facilities and, in the
case of ladders the quality of the supporting ground. It is very important to keep this in mind and try to provide access to all elements in need of maintenance. (Hermans M., 1995)

Maintenance cost division shows that the costs are equally divided between the interior and exterior of a building. Costs for maintenance are quite variable, according to the age of the building. The older the builder the higher the costs, this can be seen on Figure 2.5. This figure shows the maintenance expenses as a proportion of new building costs for residences. This graph is the result of a survey taken in Iceland in 1999. The average annual cost of maintenance works is around 2% of the building cost for a new house, calculated over 60 years. (Marteinsson B & Jonsson B. 1999)

![Figure 2.5: Annual cost of maintenance as a fraction of building cost (Marteinsson & Jonsson, 1999)](image)

2.5.7 Establishing a maintenance plan

The starting point of the process of making a maintenance plan is the inventory where all the construction elements in need of maintenance are listed. For each element the quantity (m², m, pieces) and the materials used are written down. After the inspection the current state of each element is known and it will be sorted in different categories depending on the urgency of the maintenance. With this information the periodicity of the maintenance actions, the people, material and equipment needed and the costs can be determined. (Daly J., Vijverberg G. & Van der Voordt T. 2003).
2.5.8 Factors affecting the implementation of practical maintenance

Having an efficient and detailed maintenance plan is a good strategy in theory but often it is not so easy to put the theory to practice. The practical issues of arranging and managing maintenance could delay an owner’s decision to undertake works. The building owner needs to enable access to the building which means in most cases that the owner needs to take time off from work.

Another problem that can occur is finding properly trained and qualified builders who are able to undertake maintenance on historic properties (Feilden B, 2003) and when maintenance is carried out, the materials used are often unsuitable for the property. The willingness to undertake maintenance work by building professionals may be lowers than expected. Dann N. and Cantell T. (2007) give a possible explanation for this problem: “maintenance may be less interesting than an alteration and is less attractive than a major restoration project of a historic building.”

Finding materials that can replace the traditional and original used materials can be also a major problem, especially when dealing with a very old building. The costs of this search can also be a reason to delay the maintenance works. Building owners will wait until the whole element needs replacement so that the material does not need to match the original used materials. (Forster A.M. & Kayan B. 2009)

2.6 Summary

Maintenance is a part of the building industry that deserves more attention than it gets today, it is an important part that can benefit the building and its users in several ways and both with the desired results on short term and long term time periods. Maintenance can be seen as the combination of all technical and associated administrative actions during the service life to retain or restore a building or its parts in a state in which it can perform its required functions. There are many strategies to perform maintenance and it can be planned or unplanned. A planned preventive maintenance strategy is the most cost-efficient and effective way to prevent a building to wear down sooner than wanted.

In Europe the interest for maintenance has been growing since the end of the Second World War and the with the development of the Athens and Venice charter. Ever since, several norms, standards and organization have been created to help building owners maintain their buildings. When talking about heritage, maintenance or conservation differs a bit from the non-historical buildings. The cultural significance plays a big role and cannot be neglected.
To have a good and efficient maintenance strategy it is important to have a detailed maintenance plan. This plan can be very useful when making a budget and is often needed to receive financial support from the government. Table 2.1 shows all the steps and elements that should be taken into account when making a maintenance plan.

**Table 2.1: Summary maintenance plan**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Collection information about the building</td>
</tr>
<tr>
<td></td>
<td>• General characteristics</td>
</tr>
<tr>
<td></td>
<td>• History of maintenance that has been done</td>
</tr>
<tr>
<td></td>
<td>• Cultural significance</td>
</tr>
<tr>
<td>2.</td>
<td>Maintenance strategy/policy</td>
</tr>
<tr>
<td></td>
<td>• What is required to be done?</td>
</tr>
<tr>
<td></td>
<td>• How often inspections?</td>
</tr>
<tr>
<td></td>
<td>• Where does the money come from</td>
</tr>
<tr>
<td></td>
<td>• .... Planned or unplanned maintenance strategy</td>
</tr>
<tr>
<td>3.</td>
<td>Maintenance activities</td>
</tr>
<tr>
<td></td>
<td>• Repairs/replacements, cleaning, painting, inspections</td>
</tr>
<tr>
<td></td>
<td>• Does not lead to an ‘as new condition’</td>
</tr>
<tr>
<td>4.</td>
<td>Preparing a program</td>
</tr>
<tr>
<td></td>
<td>• Long term maintenance</td>
</tr>
<tr>
<td></td>
<td>• Annual maintenance</td>
</tr>
<tr>
<td>5.</td>
<td>Inspections</td>
</tr>
<tr>
<td></td>
<td>• Required on a regular basis</td>
</tr>
<tr>
<td></td>
<td>• Monitoring Heritage System (MHS)</td>
</tr>
<tr>
<td>6.</td>
<td>Preparing a budget</td>
</tr>
<tr>
<td></td>
<td>• Committed, variable or managed expenditure</td>
</tr>
<tr>
<td>7.</td>
<td>Establishing the plan</td>
</tr>
<tr>
<td></td>
<td>• Putting all elements and information together in one plan</td>
</tr>
</tbody>
</table>

Although a maintenance plan is efficient and effective in theory, it is proven to be not so easy to put the theory to practice. The accessibility of the property, the craftsmen and materials needed can cause problems and therefore can delay or cancel the maintenance works.

In the next chapter a methodology is proposed to compare the maintenance plans for historical buildings in Belgium and Portugal. The elements discussed and summarized in Table 2.1 will be used as a starting point for the comparison of four case studies.
3 METHODOLOGY AND FIELD WORK

This third chapter proposes a methodology that will be used for the comparing study. This chapter will justify and clarify the methods that are used in chapter four. The problems that need to be considered when tackling the subject of maintenance in heritage buildings in Belgium and Portugal will be mentioned. This chapter gives more information about the tools used to compare the maintenance plans of both countries. It includes a general overview of the approach used in conducting the research, thorough descriptions of how the information is collected and analyzed. At the end of this chapter a general overview of the case studies that are used for this dissertation is given.

3.1 General description of the proposed methodology

Chapter two, State of the art, acknowledged the fact that a maintenance plan is an important tool to keep a building from wearing down sooner than wanted. It can be very useful to slow down the deterioration of an important building and its elements when talking about a building with a cultural or historical value. According to the NBN EN 15331 (2011), a maintenance plan is a ‘structured and documented set of tasks that includes the activities, procedures, resources and the time scale required to carry out maintenance.’ The main focus of maintenance is to prolong the service life of the building. In case of heritage buildings maintenance is not all about the service life, the cultural significance of the building is the determining factor. Clark (2011) puts focus on the idea that the ‘sensitive repair and maintenance of an historic building and its landscape is not just a matter of specifying traditional materials and techniques. It requires an appreciation of why the site is significant, how the significance is embodied in the fabric and what the impact potential repairs might have on it.’

A maintenance plan designed for heritage properties introduces some difficulties that must be overcome in a way that the condition and aesthetics of the building are as desired by the building owner. The maintenance plan contains both technical instructions and information regarding the costs associated with maintenance. Efficient management of the maintenance activities and routines allow not only the longevity of the service life of the elements that are inspected, it also improves the daily functioning of the building.

The flowchart that represents the methodology developed for this master dissertation with the aim of comparing the maintenance plans for historic buildings in Belgium and Portugal is shown on Figure 3.1. this methodology is based on a methodology found in a dissertation that was also about maintenance plans for historical buildings. (Soares D., 2012)
Figure 3.1: Flowchart for the proposed methodology
For this master dissertation four case studies were selected, three of them are located in Belgium and the forth one is located in Portugal. Initially, presented by the preliminary phase, information about the case studies is collected and analyzed; inspection reports, maintenance plans, drawings, plans and pictures of the building, etc. are collected. It is important for this study to know more about the history of the building. Every building is different and has a different history of use, the maintenance plan established for a building needs to be compatible with all this information. The first phase also contains a characterization of the buildings, for this characterization a first inspection sheet has been created and can be found on Figure 3.2. It is important to know more about the building when trying to understand the maintenance plan. The function and the location of the building can cause some difficulties when executing the plan. Also the way the building is being constructed and the specific materials used must be known to establish an effective and detailed maintenance plan.

<table>
<thead>
<tr>
<th>INSPECTION SHEET 1: GENERAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
</tr>
<tr>
<td>NAME</td>
</tr>
<tr>
<td>PICTURE</td>
</tr>
<tr>
<td>LOCATION</td>
</tr>
<tr>
<td>YEAR OF COMPLETION</td>
</tr>
<tr>
<td>STYLE</td>
</tr>
<tr>
<td>OWNER</td>
</tr>
<tr>
<td>FUNCTION</td>
</tr>
<tr>
<td>ORIGINAL</td>
</tr>
<tr>
<td>CURRENT</td>
</tr>
<tr>
<td>LISTED BUILDING?</td>
</tr>
<tr>
<td>RENOVATION WORKS?</td>
</tr>
<tr>
<td>WHEN?</td>
</tr>
<tr>
<td>MAINTENANCE PLAN PERIOD</td>
</tr>
</tbody>
</table>

*Figure 3.2: Example of inspection sheet 1: General description*
This first inspection sheet is also the starting point of the comparison study and will mark the end of the preliminary phase. The columns A-D are a representation of the four case studies; Alexian Monastery (A), Capuchin Cloister (B), Prelaatshof of the Sint Michael’s abbey (C) and the Jeronimos Monastery (D). The preliminary phase will be followed by a comparison phase. This comparison will be made with the focus on three aspects of the maintenance plan.

First of all a general comparison of the maintenance approach will be described and compared. The identification of the elements in need together with the determination of the physical condition, priority and periodicity of the maintenance actions are the beginning of the establishing of the maintenance plan and will also be handled in this section. For this comparison a second inspection sheet has been created. An empty example of this sheet can be found on Figure 3.3. Because the maintenance approach in the Belgian case studies do not show many differences, those three cases are grouped together.

<table>
<thead>
<tr>
<th>INSPECTION SHEET 2: IDENTIFICATION OF THE ELEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-B-C</td>
</tr>
<tr>
<td>CODING SYSTEM USED</td>
</tr>
<tr>
<td>Roofs</td>
</tr>
<tr>
<td>example</td>
</tr>
<tr>
<td>Walls</td>
</tr>
<tr>
<td>example</td>
</tr>
<tr>
<td>CONDITION OF THE ELEMENTS</td>
</tr>
<tr>
<td>PRIORITY</td>
</tr>
<tr>
<td>PERIODICITY</td>
</tr>
<tr>
<td>CULTURAL VALUE</td>
</tr>
</tbody>
</table>

Figure 3.3: Example of inspection sheet 2: Identification of the elements

A second part of the comparison of the maintenance plans in Belgium and Portugal will focus on the maintenance actions. In this part the types of actions and the way they are described in the maintenance plan will be analyzed and discussed with a special focus on the inspections. Regular inspections are at the basis of a good preventive maintenance strategy. A third inspection sheet (Figure 3.4) is established for the comparison of the inspections.
A third and final part of the comparison phase will focus on the calculation of the costs regarding the maintenance actions. There are several ways to plan and calculate the costs. In this section the methods used are compared and also the way the total costs are divided over the available years. Sometimes the available budget doesn’t match the needed budget and the alterations have to be made. The inspection sheet that has been created for this comparison can be found on Figure 3.5.
The end of the comparison phase is marked with the description of the difficulties and special elements of the maintenance plans and buildings in general. Every building is different and has different needs, it is not easy to put a theoretical plan to practice without alterations or problems that need to be solved to guarantee an effective and efficient maintenance management.

This phase will be followed by a conclusion and discussion phase in which all the differences and similarities are put together and a final conclusion will be drawn.

### 3.2 Case studies

To compare the maintenance planning and the way maintenance is tackled in historic buildings in Belgium and Portugal case studies were selected to use in this study. For these chosen buildings a maintenance plan has been established by different organizations and people.

In Belgium as mentioned in ‘2.4.3. Organizations’, Monument Watch Flanders is making maintenance plans for heritage buildings. The original organization Monument Watch has been founded in 1973 in the Netherlands by two individuals on request of a group of monument owners. (Maintain our Heritage, 2003)
The success story of this organization influenced the Flemish part of Belgium to do the same and in
1991 Monument Watch Flanders has been founded. In 2011 the organization started making
maintenance plans accompanied with cost estimations.

Because Monument Watch Flanders is a known and internationally respected organization, it is a good
starting point for this master dissertation to study their maintenance plans. Belgium is the only country
which succeeded in copying the original model. By comparing the case studies provided by Monument
Watch with the Portuguese case study the feasibility of the organization in Portugal can also be tested.

Monument Watch Flanders provided three case studies: the Alexian Monastery located in Mechelen,
The Capuchin Cloister in Antwerp and a residential building (Prelaatshof of the Sint Michael’s abbey)
also located in Antwerp. These three buildings were chosen because of their rich history and even
today the cultural value is still present. The current use of the buildings differs which makes it
interesting to compare them to each other. Monument Watch has established a maintenance plan for
these buildings in the recent past, the latest methods were used. Because Monument Watch made a
maintenance plan for all three buildings they will be grouped as much as possible in the next chapter.

The building in Portugal used in this study is the ‘Jeronimos Monastery’ located in Lisbon. This
maintenance plan was the result of a PhD thesis. (Carvalho 2009) It is a building with a cultural
significance that cannot be ignored. The Monastery is also one of the few historic buildings in Portugal
for which a maintenance plan has been established. This was one of the important reasons to choose
for this building complex. The maintenance plan however is a theoretical model and has not been put
to practice because of budgeting reasons.

3.2.1 Alexians monastery – Mechelen

This building complex, located in Mechelen, was built in the early 1700s. The monastery building was
completed in 1710 and in 1730 the chapel was finished. On this site the Alexian monks took care of
the sick, mentally ill and plague-stricken. In that time they wanted to hide the sick people from the
outside world, this explains why no, or very few windows are located on the street side façade as seen
on Figure 3.6 (left). The Alexians were evicted during the French occupation, the Franciscan nuns came
and continued their work. Today the restored and renovated building complex houses the
administrative offices of Mechelen’s hospitals and exhibitions and concerts are held at regular
intervals. The current complex (Figure 3.6, right) of four wings has been implanted around a
rectangular courtyard with the chapel and sacristy located in the southeast. In the northwest, a new
school building has been founded in 1958. The western wing is used as a youth and community center.
The building is listed as legally protected since 13 December 1977. (Eeman M., Kennes H. & Mondelaers L., 1984)

Figure 3.6: Windowless façade streetside (left) and restored view of the courtyard (right) (Monumentwacht, 2013 (left) & Stad Mechelen, 2016 (right))

3.2.2 Capuchin cloister and chapel – Antwerp

This building complex, the Capuchin cloister and chapel, used to be a cloister but has been transformed to the chair of the department public health and hosts the Master degree program of the Prince Leopold Institute for tropical medicine. The cloister has a rich history and the function of the building has changed several times in the past. Since 1625 the building hosted Carthusian monks and it became the second cloister in the city of Antwerp. In the 17th century the building has been shaped by these monks. The chapel with its west façade, in baroque style is an important element of that time. (Figure 3.7, left)

Figure 3.7: Baroque façade (left) and new added volume (right) Capuchin cloister (Monumentenwacht, 2013)
In 1782 the monks were driven out of the buildings and the cloister had been sold and subsequently used as barracks, diamond and sugar refinery. These industrial activities reduced the complex to ruins. This did not stop the Capuchin sisters to buy the old cloister in 1834 and restore the building. In 2001 the last two sisters went away and the building was bought by the Prince Leopold Institute of Tropical Medicine. This was the start of the second big renovation of the buildings which started in 2003 and were divided into two phases. First the main building of the cloister was transformed into classrooms and office spaces. Secondly the chapel was transformed into a conference room.

The building structure was too old for new technical installations needed so a new volume has been created on the outside of the building. This volume visible of Figure 3.7 (right) contains staircases, lift and sanitation. (Engels R. 2003)

3.2.3 **Prelaatshof Sint-Michielsabdij (Residential Building part of the St. Michael’s Abbey) - Antwerp**

The ‘Prelaatshof’, part of the St. Michael’s Abbey and dated from the 15th century, has been destroyed in 1630 and was rebuilt only 5 years later. The original building complex was surrounded by water and exists of four wings of one or two floors. It used to be a cloister for the annonciades sisters but today the complex provides spaces for organizations that are working around social themes. In the past the four winged complex was surrounded by canals which are now filled in and turned into a playground for the neighboring schools as shown on Figure 3.8 (left). On Figure 3.8 (right) the entrance gate is shown, this is the only structure that hints the past canals surrounding the building complex (Plomteux G. & Steyaart R., 1989)
3.2.4 The Jeronimos Monastery – Lisbon

The building complex used in Portugal to compare the maintenance plan is the Jeronimos Monastery (Figure 3.5 (left)). The building complex exists of the Santa Maria de Belém church, the cloister and the dormitory of the order of Jeronimos. In this master dissertation only the church and the cloister are discussed because they have the same management regarding maintenance. This building complex has a very rich history and is part of the main touristic attractions in Lisbon. King D. Manuel I gave the instructions to build the monastery in the 16th century as a home for the monks of St. Jeronimo’s (Hieronymites) order and serve as a pantheon for the royal dynasty of the Portuguese king. The monastery withstood the 1755 Lisbon earthquake without much damage, only the balustrade and part of the high choir were ruined but quickly repaired.

The Hieronymites occupied the monastery for 400 years until the dissolution of the monasteries in 1833, when the building became state property. Big restoration works started after 1860, starting with the southern façade (Figure 3.5 (right)) which is a perfect example of the ornate manueline style.

Figure 3.9: Jeronimos Monastery general view (left) and ornate Manueline south portal (right) (Thad R., 2007 (left) & Alves G., 2015 (right))
3.3 Chapter summary

This chapter described and justified the proposed methodology for this master dissertation. In this chapter more information about the methods and tools that will be used for the comparison study of the maintenance plans in Belgium and Portugal is given. For this study four case studies with a historical background were carefully selected.

The methodology can be divided in three phases; a preliminary phase, a comparison phase and finally a concluding and discussion phase. In the first phase the information needed will be collected and analyzed. All the general information about the four cases will be summarized in the first inspection sheet. This sheet will be the starting point of the comparison phase where the building complexes will be compared with the focus on different aspects of maintenance. In chapter two, State of the art, the most important elements of a maintenance plan were described. In the next chapter the way this theory is put to practice will be discussed. The maintenance and maintenance plans established will be first compared in a general way together with the identification of the elements in need of maintenance. The second aspect that will be discussed are the maintenance activities that are included in the maintenance plan. Finally the methods used for the calculation of costs will be compared and discussed. At the end of chapter four all these findings will be put together to form a conclusion.

At the end of this chapter the four case studies that were selected were described and some historical background was given. Three of the building complexes that will be used in the next chapter are located in Belgium. The maintenance plan for these buildings is made by the organization ‘Monument Watch Flanders’. The fourth building is located in Lisbon, Portugal and its maintenance plan was the result of a PhD thesis. (Carvalho, 2009)
4 CASE STUDIES AND COMPARISON

This chapter includes the four case studies and the comparison of their maintenance plans. The focus will be on the construction aspect of the building complexes instead of the history of the building as this is already given in chapter three. After a short construction description the comparison will be followed. The three cases that are located in Belgium will be combined together because of the few difference in maintenance plan. The comparison will be made with the focus on several aspects on maintenance such as the general maintenance approach and identification of the elements in need, the maintenance actions that are described and the methods of cost calculation and budgeting. At the end of this chapter all the results will be put together and discussed and a conclusion will be formed.

4.1 Construction description

As seen on the flowchart, Figure 3.1, will this master dissertation be divided into three phases. The first phase is the preliminary phase where the information is collected and analyzed. The case studies will be described in a general manner. It is important to know the building as detailed as possible to really understand the maintenance approach and the measures that should be taken to provide an maintain the building. Every building is different and so will the maintenance plan that is established for each building complex. This paragraph will include a description of the case studies with the focus on the construction and the materials that are used. This paragraph will include a first inspection sheet at the end that will summarize all the information that will be needed for the actual comparison of the maintenance plans.

4.1.1 Alexian Monastery (A) – Mechelen

The first case study, located in Mechelen in Belgium is the Alexian Monastery, this building complex was built in a Baroque style with the use of brick walls and some sandstone and bluestone details. The whole complex can be seen as a connection of three buildings with a different appearance. The chapel (Figure 4.1 left) built with traditional bricks and sandstone details really shows the Baroque style. The monastery has a totally different appearance. The streetside façade is built with ‘Balegemse stones’ which is a strongly calcareous sandstone, mined in the Belgian district of Balegem. The stone can also be categorized as a sandy limestone. The façades of the monastery that face the inner courtyard have been finished with a coat of plaster, this can be seen on Figure 4.1 (right). The third building that is a part of this complex is a building that stands out because of its red colour. (Figure 4.2)
It is a simple pitched roof building built with traditional bricks and has had a red paint coat. The glass construction that connects the old building to some newly built building is not included in the maintenance plan and will not be further discussed. Because of the restoration of the walls, the hard protective coating of the stones have been affected. This way the building could endure some moisture and frost damage.

![Image of the building](image1)

*Figure 4.1: Chapel (Left) and monastery (right) of Alexian monks (Left: taken from google maps, 2014 & Right: Monumentenwacht 2012)*

The roofing plan (Figure 4.3) shows an overview of the site that will be discussed. All the roofs are pitched and are covered in slates that are kept in place with stainless brackets. The building has been abandoned for some time and has been renovated at the end of the ‘90s. Beams, rafters and purlins display numerous cracks caused by reusing and heating the different attic spaces.

![Image of the roofing plan](image2)

*Figure 4.2: Red painted building Alexian monastery (taken from google maps, 2014)*

*Figure 4.3: Roofing plan Alexian Monastery (Monumentenwacht 2012)*
4.1.2 Capuchin cloister and chapel (B) – Antwerp

The second case study is a building complex existing of a former cloister and a chapel, both built in the 17th century and hosted Carthusian monks since that day. After some industrial industry the building was reduced to ruins and needed some renovation which it received in 1834. The second and last big renovations works were performed around 2003 where the building transformed from a cloister to an institutional building with class rooms, office spaces and a conference room located in the chapel.

The chapel, of which the latest addition dated from the end of the 17th century exist of one aisle and has a façade that is the result of the transition from a traditional brick and sandstone style, which can still be seen in the cloister wing.(Figure 4.4 (left)) It is an example of the assimilation by local architects of the from Italy to Antwerp imported stylistic characteristics of the Baroque style.

![Figure 4.4: Façade cloister (left) and accompanying freestanding building (right) (monumentenwacht 2013)](image)

The cloister west of the chapel consists of a square courtyard with buildings on both western and southern side. The façade facing the street is built in traditional brick and sandstone and dates from the second quarter of the 17th century. (Figure 4.4 (left)). The building complex for which Monument Watch made a maintenance plan also includes another accompanying freestanding building that can be seen on Figure 4.4 (right). This building differs a bit from the other building, not only because of the tiled roof but also because less sandstone was used. On the roofing plan that can be found on Figure 4.5 the different buildings and roofs are shown. The pitched roofs are marked in red and blue, the red buildings have a tiled roof coverage while the blue ones are covered with slates kept in place with stainless brackets. The black and grey areas are representing building parts that have a flat roof covered with small boulders.
4.1.3 Former St. Michael’s estate (C) – Antwerp

The third and final case study chosen in Belgium is the former ‘Prelaatshof’ or St. Michael’s estate in Antwerp. The Dutch word ‘hof’ refers to an by canals, hedgerows or fences enclosed area. In this case the buildings, built around a rectangular courtyard were surrounded by canals. These canals were in a later time period filled in and now those areas serve as a playground for the neighboring schools. Traditional bricks are used for the structure of the building, the condition of these bricks is decent but several cracks have occurred that were treated in a bad way in the past. Since this building didn’t had a big important function in the past its appearance is kept rather simple and traditional. Even today hidden behind other buildings, not even visible from the street is it the only building used for this master dissertation that isn’t listed. Figure 4.6 (left) shows the location of this building complex, hidden behind school buildings. The roofing plan is shown on Figure 4.6 (right), the largest share of roofs are pitched, but also some flat roofs are present. The pitched roofs are marked in blue and are covered with slates, nailed to the roof structure.
4.1.4 Jeronimos Monastery (D) – Lisbon

The building complex that is located in Portugal is the Jeronimos Monastery in Lisbon. The complex existing of a church, cloister and dormitory is divided in two and only the church and cloister are being discussed in this master dissertation.(Figure 4.7). The monastery was designed in a manner that later became known as Manueline: a richly ornate architectural style with complex sculptural themes incorporating maritime elements and objects discovered during naval expeditions, carved in lime stone as seen on Figure 4.8. For the construction of the building complex, calcário de lioz, a gold-colored limestone has been used. The pitched roofs are covered in red tiles.

![Figure 4.7: Jeronimos Monastery (taken from Google maps, 2016)](image1)

![Figure 4.8: Ornate decorated carvings in limestone (taken from lisbon-portugal-guide.com, 2016)](image2)
4.1.5 Synthesis

The most important and relevant information for this study will be summarized in Table 4.1. In this table all the case studies are put next to each other to have a good overview of what will be used for this study.

Table 4.1: Inspection sheet 1: Construction description

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>Alexian monastery</td>
<td>Capuchin cloister</td>
<td>St. Michael’s Estate</td>
</tr>
<tr>
<td>PICTURE</td>
<td>![Picture A]</td>
<td>![Picture B]</td>
<td>![Picture C]</td>
</tr>
<tr>
<td>LOCATION</td>
<td>MECHELEN</td>
<td>ANTWERP</td>
<td>ANTWERP</td>
</tr>
<tr>
<td>YEAR OF COMPLETION</td>
<td>1555</td>
<td>1625</td>
<td>1635</td>
</tr>
<tr>
<td>STYLE</td>
<td>Baroque</td>
<td>Baroque</td>
<td>Traditional</td>
</tr>
<tr>
<td>OWNER</td>
<td>Emmaus vzw (organisation)</td>
<td>Institute for tropical medicine</td>
<td>Private owner</td>
</tr>
<tr>
<td>FUNCTION</td>
<td>Monastery</td>
<td>Cloister + chapel</td>
<td>Estate of the st. Michael’s abbey</td>
</tr>
<tr>
<td>ORIGINAL</td>
<td>Administrative</td>
<td>Educational</td>
<td>Residence</td>
</tr>
<tr>
<td>CURRENT</td>
<td>Administrative</td>
<td>Educational</td>
<td>Residence</td>
</tr>
<tr>
<td>RENOVATION WORKS?</td>
<td>Yes interior</td>
<td>Yes</td>
<td>Yes interior</td>
</tr>
</tbody>
</table>
This first inspection sheet marks the end of the preliminary phase, the information is collected, analyzed and the case studies are being described with the focus on the construction and the materials that were used. In the second phase, the comparison phase the maintenance plans will be put next to each other and the similarities, differences and special elements will be discussed. As mentioned before will the Belgian case studies be grouped as much as possible. The maintenance plans for all the three buildings have been established by the same organization, so the approach will be more or less the same. In the next paragraphs, the general structure of the maintenance plan, the identification of the elements in need of maintenance, the maintenance actions with a special focus on the inspections and the costs will be compared.

4.2 Maintenance approach and identification of the elements in need of maintenance

This section contains the general comparison of the maintenance approach in both countries. The first step in the maintenance process is making the decision to undertake some action, preferably in a preventive manner. When the decision is made the elements in need of maintenance should be identified in an unambiguously way; this is important when the maintenance work is carried out. The condition of the elements and the needed maintenance activities have to be determined next. A maintenance plan is established to help the building owner with planning the maintenance activities, the plan will group and combine the actions so that the building and its elements will perform as desired. A second goal of the maintenance plan is to keep the appearance of the building as close to the original appearance as possible.

4.2.1 Maintenance approach and element identification in the Belgian case studies

In Belgium the creation of a maintenance plan is not mandatory but desired when dealing with heritage. Many historic building owners do have a maintenance plan for their building because of the promised financial help of the government. Because it is not easy to make a maintenance plan yourself the owners ask the Flemish organization Monument Watch to help them with this, the organization also offers advice and annual inspections for their members who pay a yearly contribution.

The makers of the maintenance plans use an inspection report as a starting point. These reports are be described in a more detailed manner in paragraph 4.3.1 Maintenance actions in the Belgian case studies. The inspectors of Monument Watch will first go to the buildings and inspect every element, they will write down recommendations and give advice to the building owner. With this report the maintenance plan can be created, another less detailed inspection will be performed but this only to check and note the amount of materials and elements used.
The maintenance plan combines the planning of the activities with a cost estimation. Monument Watch only inspects, gives advice and establishes the maintenance plan, the organization is not responsible for the execution of the maintenance actions that are written down in the plan. A translated version of the Alexian Monastery maintenance plan can be found in Appendix 1. Only the important and/or relevant information is translated from Dutch to English and is shown in the Appendix. The following elements are included in the maintenance plan of the three Belgian case studies:

- **Report code.** The maintenance plan is based on an inspection report. Every anomaly or action written down in the report gets a code. The maintenance activities together with their corresponding codes can be found in the maintenance planning table.

- **Location in the building.** In this column the location of the element that is in need of maintenance is written down, the manner in which this is done is described further in this paragraph.

- **Description.** The third and biggest column contains the description of the maintenance activity. The activities are described with few words but together with the report code the longer and more detailed description can be found in the inspection report.

- **Measuring code.** To make sure that no confusion or mistakes will occur it is important to mention in which measuring unit the quantities will be measured. In these cases four codes are used: sum over all or forfeit, expected quantity, unit per hour and unit per piece.

- **Unit and quantity.** The next two columns will serve to fill in the quantity of the maintenance task and the unit in which it is measured.

- **Frequency.** Most maintenance actions need to be repeated several times over the time period of the maintenance plan. In this column the frequency of those actions are written down.

- **Price/unit and total/year.** The following column is established to fill in the price per unit. This column multiplied with the quantity gives the total per year and is written down in the ninth column.

The right side of the maintenance planning table is reserved for the years that are included in the plan. Monument watch choses to keep the maintenance plan rather limited regarding the time period, 5-6 years is an average time period for which they make a plan. Normally the maintenance plan will not be updated every year in a detailed way, only when the owner desires it or when the annual inspection shows that an adaptation of the maintenance is necessary changes are made.
The maintenance activities are grouped as much as possible, for example all the maintenance activities that are located on the roof are put together in the same year. This way the owner of the building only needs to contact a specialized roofing contractor every 5/6 years dependable on the tasks that need to be performed. The actions that have a high priority are planned in the first year of the plan and the other tasks are spread as equally as possible.

To make an easy to read and understandable plan it is important to identify the elements that are in need of maintenance. This is not only important for the people who make the maintenance plan, it is also very important for the contractors. They have not done the inspection so they do not know exactly where the problems are located. For the localization of the elements a coding system is used, by doing this confusion and mistake will be avoided. With the maintenance plan and inspection report a roofing plan is added, an example of this plan can be found on Figure 4.3. On this plan, the different roofs are shown, each roof is marked with a different number. When talking about a specific roof, the code ‘roof’ is used plus the number that matches the roof on the roofing plan. When talking about a specific façade the same roofing plan will be used for the identification. The element will get the name ‘façade’ plus the number of the roof above it and the orientation of the façade. This is a very easy but not very detailed system.

The condition of the elements is described on two levels and is marked with a letter; G (= good), R (= reasonable), M (= moderate), B (= bad) and N (= not inspected). Based on these marks the actions needed to upgrade the condition will be planned in the maintenance plan. It is easy to understand that elements in a bad condition are prior to elements with a good or reasonable condition. First the general condition of the material of the collection of elements will be graded with a percentage. For example in the Capuchin cloister the roofs are covered with slates, tiles and the flat roofs are covered with little boulders. The condition of the tiles is 100% good, the roof has been replaced in 2003 and no anomalies have been found. The slates are not in a perfect condition, they get a 85% good, 10% moderate and 5% bad grade. Generally speaking the slates are in a good condition but in some places there are things that need to be fixed. The moderate grade is used when an element needs repair but it is not so urgent, at the moment the problems are not causing any problem. The elements that got a bad grade did cause a leakage, the effects of this leakage are minor but this needs to be repaired as soon as possible. The boulder layer on the flat roofs covers the rubber coating, this makes it difficult to inspect. The grade ‘N’ (= not inspected) is used for 70% of the element grade.
4.2.2 Maintenance approach and element identification in the Portuguese case study

In Portugal it is also not mandatory to have a maintenance plan and in contrast to Belgium few buildings have a maintenance plan. Because of the importance of the Jeronimos Monastery it is desired to have a preventive maintenance approach where a maintenance plan is a useful tool. The primary objective of the maintenance is not to gain more income but it is to maintain the cultural value by keeping the physical appearance as close as possible to the original appearance.

The maintenance plan that has been established for the Jeronimos Monastery is the result of a PhD dissertation and a translated version can be found in Appendix 2., it is based on both Italian and British models and its approach is very theoretical. The maintenance plan that is proposed consists of seven columns and are mentioned below:

- **Coding of the technological system**: in this first column the location of the elements in need of maintenance are written down, to do this a coding system is used. This system will be further explained in this paragraph.
- **Routines**: here the maintenance actions are mentioned, the description of the works is limited to cleaning, inspecting, repairing, painting, ...
- **Periodicity**: the periodicity of the maintenance actions are shown in this column, a cross must be placed under the right periodicity ( once, monthly, quarterly, semi-annual, annual, bi-annual or five-year)
- **Frequency (bad weather)**: in this column a cross is put when special care is needed when the weather is bad.
- **Necessities**: this column shows what is needed for this specific actions, how many people, which equipment and special services will be written down in this column.
- **Cost per job**: as the name says it all, this column calculates the cost of the job
- **Annual budget**: if the actions are repeated during the year, the annual budget will be different than the cost per job.

The design of the Jeronimos Monastery is very complicated so a detailed coding system should be used to located the elements that are in need of maintenance. The coding system that has been used for this maintenance plan is based on an Italian coding system (UNI 8290-1: 1981) and consists of an alphanumeric code, consisting of two parts: identification of the element in the context of the construction system (in text characters) and its functional location and sequentially numbered (in Arabic numerals). An adaptation has been made to make the system available for historic buildings. An example of this coding system can be found on Figure 4.9.
Figure 4.9: Example of element identification Jeronimos Monastery

- Technical class: Vãos (VAo) which can be translated to span
- Constructive element: Vitral decorativo (Vd); the element that is described is a decorative stained glass element.
- The element is located on the main façade (075) and
- The specific element that is coded is the fifth window on that façade.

Together with these codes a manual is needed to understand the meaning of all the codes and to make sure no confusion or mistakes are made. There are also sheets included that show parts of the monastery and the code of each element is attached to the element on the picture. This way the coding system is explained in a visual way. This can be very useful especially for the last part of the code, in the example a 5 is noted but it can be difficult to figure out which window the fifth is.

The condition of the elements is based on three aspects: the actual assessment of the physical condition of the element (PC), its cultural value (CV) and their criticality (C); these three aspects combined defines the priority of the actions of the element (P) which can be very useful when making the maintenance plan.

i) Physical condition of the element (PC)

First of all the physical condition of the element will be determined, this can be easily done by direct observation in site. A numerical scale is used to label the condition of the element

- Ruins (1): Does not respond to performance, it involves structural loss, functional or aesthetic. There is a risk of structural collapse, cultural loss and danger to users. Total replacement is desired.
- Bad (2): lack of maintenance or poor performance, may involve partial replacements.

ii) Cultural value (CV)

The appreciation of the cultural value is based on the evaluation of characteristics such as artistic importance, historical authenticity or the aesthetic value of the element. A numerical scale is also used for this evaluation.
- Significant (1): element of the original state (XVI to XVIII), associated with important facts
- Relative (2): resulting element amended (XIX – XX centuries) associated with important campaigns of work of recognized author or relative decorative value.
- Low (3): monitoring element without significant historical association or decorative value.
- Worthless (4): constructive element without historical, artistic or aesthetic value.

iii) Criticallity (C)

Maintenance of a building also depends on the conditions of executions of the work, including the accessibility and safety conditions. This criteria is also divided in four levels

- High (1): element with difficult or no access, to carry out the work induces risk to physical integrity.
- Average (2): Element whose accessibility entails using specific means, the implementation of the work requires special security measures.
- Low(3): element with good accessibility, performance of work requires measures regarding current security, the condition partially affects the remaining structure or elements.
- None(4): element with good accessibility, the execution of the work does not affect the remaining structure or elements

These three criteria’s put together will decide the priority of the maintenance work of that specific element. A formula has been established (Saraiva Cabral, 1998 and Carvalho 2007) for the determination: PC x CV x C, the solution of this equation can vary between 1 (highest priority) to 64 (lowest priority). With these numbers the maintenance plan can be established.

4.2.3 Comparison of the maintenance approach and element identification

The biggest difference is the experience of the makers of the maintenance plan, the Belgian maintenance plan is established using a lot of experience. The Portuguese maintenance plan is a result of a PhD thesis and is very theoretical and is one of the only maintenance plans for historical buildings that is available in Portugal. For this comparison of the general maintenance approach and the identification of the elements in need of maintenance inspection sheet 2 is created and filled in (Table 4.2). Because there is no significant difference between the cases in Belgium they are grouped together.

One of the things that can be noted is that both countries use a coding system to identify the elements in need of maintenance, however the system is very different from each other.
The system used in Belgium is very limited and minimal while the Portuguese one is very detailed and does need some explanation, because most of the maintenance activities will be performed by a permanent team the codes will be known after a while. In Belgium the building owner needs to choose a contractor for every task, it is thus important that the identification of the elements is very clear and easy to read.

Table 4.2: Inspection sheet 2: Identification of the elements

<table>
<thead>
<tr>
<th>CODING SYSTEM USED</th>
<th>A – B – C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roofs</td>
<td>‘roof + number (roofing plan)’</td>
<td>‘roof + number (roofing plan)’</td>
</tr>
<tr>
<td>example</td>
<td>Roof [12]</td>
<td>VaO Vd 075 – 5</td>
</tr>
<tr>
<td>Walls</td>
<td>‘façade’ + corresponding roof + orientation</td>
<td>‘façade’ + corresponding roof + orientation</td>
</tr>
</tbody>
</table>

The determination of the condition of the elements is also very different in both countries although they have the same basis. They both use a grading system to show the condition of the elements. In Portugal a numeral grading system is used to determine the other factors that will lead to the actual planning of the maintenance actions, while in Belgium experience is used when making the plan. This again shows the lack of experience in Portugal regarding maintenance planning in historic buildings. It can also be noted that the Belgian maintenance plan does not pay attention to the cultural value of the building and its elements. In the Portuguese maintenance plan this is an important factor in the formula used to determine the priority of the maintenance.
4.3 Maintenance actions

This section focuses on the maintenance actions that are included in the plan and how they are described. One of the most important maintenance actions when aiming at an effective and preventive maintenance strategies are regular inspections, this section will put some focus on this activity.

4.3.1 Maintenance actions in the Belgian case studies

Monument Watch Flanders is only responsible for the establishing of the maintenance plan. The owner is responsible for the execution of the plan and can choose for every action who will carry out the work.

The actions mentioned in the plan are inspections, little repairs and replacements, painting and cleaning jobs. It can be noted that the cleaning jobs are mostly small and the maintenance plan suggest that the owner should take care of cleaning the building himself.

The maintenance tasks are not described in a detailed manner, it is the job of the chosen contractor to decide how the work will be done and what materials will be used for it. The maintenance plan does include a cost estimation of the site installation and the heavy tools (steeplejack, scaffolding, …) dependable on the works that were planned in that year.

The plan also includes actions and measures that should be taken to enlarge the accessibility of the elements. Mostly ladder hooks are missing and are desired by the Monument Watch inspectors.

Inspections are probably the most important maintenance action of all. Inspection sheet 3: inspections that can be found in Table 4.3 and collects all the important information about the inspections in the Belgian buildings.

When making a maintenance plan, Monument Watch Flanders, starts with a detailed inspection of the building complex. They use a general building inventory that contains the following sectors: 1. Roofing, 2. Roof penetrations, 3. Roof Structure and attic, 4. Façades, 5. Interior, 6. Technical installations, 7. Other interior elements, 8. Climate, 9. Prevention and fire safety, 10. Accessibility and hygiene and finally 11. The surroundings are inspected. Depending on the desires and the facilities of the building these sections are being used for the inspection report.

The inspections focus on three subjects: accessibility, good conservation of the monument and sustainable maintenance. The accessibility is an important factor but is often forgotten because it is not a part of the actual monument. It is important because when performing maintenance actions the elements need to be accessible in a safe way.
## Table 4.3: Inspection sheet 3: Inspections in Belgium

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LATEST INSPECTION DATE</strong></td>
<td>10 &amp; 17/10/2012</td>
<td>08/2011</td>
<td>03/2010 &amp; 04/2010</td>
</tr>
<tr>
<td><strong>PERIODICITY OF THE INSPECTIONS</strong></td>
<td>Biennially</td>
<td>Triennial</td>
<td>Triennial</td>
</tr>
<tr>
<td><strong>DURANCE OF THE INSPECTION</strong></td>
<td>16h</td>
<td>10h</td>
<td>15h30</td>
</tr>
<tr>
<td><strong>REPAIRS/REPLACEMENTS DURING INSPECTION</strong></td>
<td>Yes</td>
<td>no</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>which repairs ?</strong></td>
<td>Closing a brazing seam</td>
<td>/</td>
<td>Some loose rocks are removed</td>
</tr>
<tr>
<td><strong>MONITORING SYSTEMS USED</strong></td>
<td>Yes, crack monitoring</td>
<td>No</td>
<td>Not yet, crack monitoring is recommended</td>
</tr>
<tr>
<td><strong>FOCUS ON SPECIAL ELEMENTS</strong></td>
<td>No</td>
<td>no</td>
<td>No</td>
</tr>
<tr>
<td><strong>INSPECTION FOR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction and stability</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Safety and accessibility</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HOW ARE ANOMALIES DESCRIBED</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pictures</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Text</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

This table shows that the inspections are actually not annual but in two of the three cases only performed once every three years. Because of the condition of the buildings and the fact that there is a maintenance plan for these cases the annual inspection service of Monument Watch is adapted to biennial or triennial inspections. During these inspections little repairs can be done.

The maintenance plan does not only include the inspections that are performed by the inspectors of Monument Watch, the plan also suggests inspections of the roof with cleaning of the gutters included in the same activity post. It is easy for the contractor who will be responsible for cleaning the gutters to check if the roof is still in a good condition.
To make reading the report easier for both the building owner and the contractor, some pictures have been added. The pictures show the problem areas which are sometimes a bit hard to describe.

i) Alexian Monastery

This monastery is since a long time a member of the Monument Watch organization and many inspections have been performed. In the latest inspection report there will always be a reference to the previous one, commenting on the new situation of the problem that was mentioned. In this case the brickwork showed many cracks, the inspectors put some marks at the ends of the cracks so that when they will inspect the building again they can see if the crack has been growing or staying stable. To measure the cracks, crack gauges have been installed and used. These manual measuring instruments (Figure 4.10) can be used to monitor horizontal or vertical movement across a crack on a flat surface.

![Figure 4.10: Crack monitor: Alexian Monastery (Monument Watch 2012)](image)

The crack monitor is initially placed over the crack with the vertical zero line on the calibration scale parallel with the crack to be monitored. The monitor will be fixed onto the surface with screws or another adhesive. If the crack opens or closes the cursor moves relative to the calibration scale. The opening or closing of the crack can then be recorded on the record sheet, which can be found on the right side of Figure 4.10. The blue line shows the first time the crack was monitored, in august 2008, the yellow line shows the inspection in 2010 and the most recent one is the green dotted line. Because all the lines are closely together the crack isn’t opening or closing so much, which is desired.

ii) Capuchin cloister and chapel

Special in this case is that the general inspections are not annual but triennial. This is probably because the building has been recently renovated completely in 2003.
Also in this case study several severe cracks were noticed, since this was the first inspection Monument Watch advises the building owner to install crack monitors. It is now up to the owner to decide whether he will do this.

4.3.2 Maintenance actions in the Portuguese case study

A first question that needs to be answered regarding the maintenance actions is how these actions are being grouped. There are three ways to do this, or the actions can be organized and grouped depending on the location of the work to be done (coverage, façades, interior) or by type material (stone, tile, floor) or according to the type of work involved (bricklayer, plumber, ...). This is important when making the maintenance plan. In the case of the Jeronimos Monastery it is important that the works are done with as little disturbance as possible to not loose many touristic activities. The first method, the criteria of location/element, seems in this context the best method to group the maintenance works.

A proposed division of the actions can be made according to its everyday nature, periodic or improvement; three divisions are made: cyclical, structural and extraordinary maintenance.

The cyclical maintenance includes replacement of consumables (lamps, air conditioning filters, fire extinguishers, etc.), cleaning of storm drains, monitoring of installed systems, verification of the outer casing and all actions in the context of a reactive maintenance (broken glass) or opportunity (displaced tiles).

Structural maintenance is related to the physical condition of the monument and it’s the medium-term conservation. It includes the application of periodic treatments such as waterproofing the terraces.

A third maintenance is the extraordinary maintenance and its perspective is long-term in order to restore the monument in a good condition. Included in this category are the implementation of new roofing tiles, cleaning the exterior surfaces of stone or renewal of the grid.

The maintenance plan that has been established includes the team that is responsible for the maintenance. To carry out the work maintenance fiches have been created to support the maintenance team and includes three types of information: the object of the intervention (elements to intervene, their physical condition, function and their priority), the nature of the tasks (description and following the work and type of action) and the needs (accessibility, humans needed and equipment). When the maintenance is being performed by third parties it is recommended to use the
collaborators sheet through which also includes some useful information about the monastery (accessibility, key chains, energy use, etc.) as well as the safety rules and operation of the building.

4.3.3 Comparison of the maintenance actions

The most important difference between the maintenance actions in Belgium and Portugal is that there is a lack of maintenance team in the Belgian plan. Monument Watch only provides the plan but does not include the needed team for executing the plan. In case of the Jeronimos Monastery a team is already present and can be used for the small maintenance tasks. When bigger tasks, for example repairs on the roof, replacement of windows, etc. the work will be carried out to known contractors. In case of the Belgian case studies the building owner is free to choose the contractor or can do the work himself. Another difference between both countries is the definition of maintenance actions, the Belgian case maintenance plan does not include simple tasks like cleaning or repairs in the interior while the Portuguese approach also includes this and defines these tasks as cyclical maintenance.

4.4 Costs and budgeting

Determining the costs can be difficult because no matter what, it keeps on being a guessing game. Especially for works in the far future it is hard to determine how much the maintenance actions will cost.

4.4.1 Costs and budgeting in the Belgian case studies

Because Monument Watch does not perform the actions the costs are just an estimation. They use a cost inventory to calculate the costs. In their report they add that the prices are just indicative, it can help to maintain the building and reduce the costs. The maintenance plan does not think about the possible available budget, if this budget is smaller than the budget needed for the various maintenance actions, alterations have to be made.

i) Alexian Monastery

The distribution of the works and the costs can be found in Table 4.4, the total costs of this maintenance period are estimated around €265 000 and are not equally spread over the years. The fourth year, in which the roof is being worked on needs almost half of the total estimated budget. This is important to know before so that measures can be taken to have that amount of money available in that year.
Table 4.4: Distribution of the works and costs Alexian Monastery

<table>
<thead>
<tr>
<th>Year</th>
<th>Activities</th>
<th>Total costs (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>Improving the accessibility and safety attic space</td>
<td>7 845,00</td>
</tr>
<tr>
<td>2014</td>
<td>Exterior joinery + maintenance painting</td>
<td>34 271,65</td>
</tr>
<tr>
<td>2015</td>
<td>Façade works</td>
<td>1 904,63</td>
</tr>
<tr>
<td>2016</td>
<td>Roof works + improving accessibility and safety roofs</td>
<td>102 952,15</td>
</tr>
<tr>
<td>2017</td>
<td>Painting the façades</td>
<td>82 574,38</td>
</tr>
<tr>
<td>2018</td>
<td>Repairs of the interior plaster layer and painting</td>
<td>392,52</td>
</tr>
</tbody>
</table>

ii) Prelaatshof

The distribution of the works and the costs of the Prelaatshof can be found in Table 4.5. Special in this case is that the measures for optimizing the safety and accessibility is only planned in the last year, in the previous case studies these actions were more prior and were planned in the first year. Also special is that the repairs of the façades are spread over two years but not two years that follow each other. The total costs of this maintenance period are around €200 000.

Table 4.5: Distribution of the works and the costs ‘Prelaatshof’ St. Michael’s Abbey

<table>
<thead>
<tr>
<th>Year</th>
<th>Activities</th>
<th>Total costs (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Roofing works</td>
<td>7 800,11</td>
</tr>
<tr>
<td>2015</td>
<td>Repairs façades facing the courtyard</td>
<td>8 366,31</td>
</tr>
<tr>
<td>2016</td>
<td>Repairs exterior joinery + maintenance painting</td>
<td>10 243,36</td>
</tr>
<tr>
<td>2017</td>
<td>Repairs façades facing the neighbors</td>
<td>77 493,49</td>
</tr>
<tr>
<td>2018</td>
<td>Maintenance painting</td>
<td>49 265,39</td>
</tr>
<tr>
<td>2019</td>
<td>Measures for optimizing safety and accessibility</td>
<td>17 122,36</td>
</tr>
</tbody>
</table>
4.4.2 Costs and budgeting in the Portuguese case study

In this maintenance plan the idea that the cost of maintaining a property can be estimated at around 2-3% of the building value. For a historical building it is very difficult to put a number on the building value. In 2005, the building value has been estimated at a total value of 280.8 million euros divided by 219.6 million euros for the church and cloister and 61.2 million euros for the former dormitory (these calculations are an estimation and not based on detailed numbers). In the case of the Jeronimos Monastery this would mean that the annual maintenance cost would be between 552 000 and 842 000 euros. When looking at the expenses of the previous years it can be noted that this amount is higher than the average investment in the monument, over the last decade.

The methodology used for the cost estimation in this maintenance plan divides the conservation tasks in two types – regular interventions and beneficiations (extraordinary maintenance). The calculation of the costs associated to the first looks at the materials and people that are needed and multiply this with the price per unit or hour. The second type is calculated using the history of interventions, transforming the prices of that time to current prices.

The regular interventions contain both cyclical maintenance and structural maintenance. In this maintenance plan, the tasks are grouped based on the type of the tasks and only the tasks regarding the cover of the building.

The first group of tasks can be seen as cyclical maintenance tasks, it includes; the execution of the annual, biennial, periodic replacements, specific fixes and discretionary budget. The structural maintenance tasks include the revision of the pluvial system and the waterproofing of the terraces. These are actions that will be performed only once. The maintenance tasks that are extraordinary including the roof repair has the biggest impact on the total cost; it represents 56.02% of the total costs of the decennia. The interior maintenance is not included in this maintenance plan.

The maintenance plan also includes a 15% margin for unexpected maintenance actions and costs. To keep up with the changing prices 3% will be added because of the inflation of the prices.
4.4.3 Comparison of the cost calculations

To compare the calculation of the costs, the fourth inspection sheet has been filled in and can be seen on Table 4.6.

Table 4.6: Inspection sheet 4: costs and budgeting

<table>
<thead>
<tr>
<th>METHOD USED</th>
<th>A – C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on previous maintenance works</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Based on price inventory</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>X (based on materials and hours worked)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ALTERATIONS BASED ON THE AVAILABLE BUDGET</th>
<th>Not mentioned</th>
<th>Not mentioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>COSTS EQUALLY SPREAD</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>EXTRA COSTS INCLUDED IN THE PLAN</td>
<td>Yes</td>
<td>Not mentioned</td>
</tr>
<tr>
<td>MARGIN FOR UNEXPECTED COSTS</td>
<td>Yes 15%</td>
<td>Yes 15%</td>
</tr>
</tbody>
</table>

The way of calculating the costs differs for both countries. The Belgian approach for this is to use a price inventory and is in general based on experience. Because Portugal lacks experience regarding maintenance plans, this method is not used in the Jeronimos Monastery, a more technical method is used. The maintenance actions are divided in two groups; regular interventions and extra ordinary interventions. The costs of the regular interventions are calculated based on the materials and people needed; the cost of the materials will be multiplied by the amount of people needed for the work and the price per hour work. The cost of the extraordinary interventions is calculated based on historical interventions. The price of these previous interventions will be transformed to current prices using a transformation factor. Both maintenance plans include a 15% margin for unexpected costs because not all maintenance actions can be predicted this is needed and is good when planning the budget that is needed.
4.5 Difficulties and special elements

4.5.1 Capuchin cloister and chapel

This case study does not contain difficulties or special elements. It can be noted that not all the works are defined as maintenance works. A statue located in the façade of the building is in desperate need of a new layer of paint. Because of the complexity of this statue it is recommended to contact a specialized contractor. This painting job is not defined as maintenance but as restoration.

4.5.2 Prelaatshof St. Michael’s abbey

A special and remarkable comment about this building complex is that the plumbing was recently replaced with plastic ones. Monument Watch comments on this that plastic isn’t a sustainable material and it doesn’t belong on a building with a historic value. The difficulty that can occur when executing the maintenance plan is that the building is not located close to a street, the building is hidden behind other buildings.

4.5.3 Jeronimos Monastery

The biggest difficulty when maintaining this building complex is the fact that it is the most important cultural building in the historical area of Lisbon. Many tourists are visiting the monastery every day. The maintenance tasks have to be planned in such a manner that there is as little disturbance as possible. The bigger maintenance actions are not planned in December, because of the many holidays and the bad weather, and in August because this is the month with the most tourists in the city.

4.6 Discussion and conclusion

All the previous comparisons are collected and put together in a final comparison of the maintenance plans and approaches in Belgium and Portugal. A different comparison sheet is established for this and can be found in Appendix 3. This appendix compares the theoretical elements that are discussed in chapter 2, state of the art, and the elements described in chapter 4 using the case studies. This comparison is made visual by using a color gradient scale. For every criteria a gradient scale is used going from green, which represents the best option to red which represents the worst or least effective option.
To decide what the best or worst option is, the theory of chapter 2 is used. An example is shown on Figure 4.11, on this figure the maintenance strategy is discussed. The green side of the scale represents a preventive maintenance which has been proven to be the best or most effective maintenance strategy. A reactive maintenance is to be avoided and is in this case represented by the color red. The comparison study has shown that Belgium uses a more preventive strategy in general while in Portugal a more reactive strategy is used. The flag-sliders show this on the color gradient scale.

![MAINTENANCE STRATEGY](image)

Figure 4.11: Example of gradient scale (maintenance strategy)

The comparison follows the proposed methodology and divides the comparison in three categories; general approach and identification of the elements, maintenance actions and finally costs and budgeting. In this concluding comparison another category has been added namely the execution of the plan in which is marked if the theory of the maintenance plan is put to practice. At the end of this comparison, all the criteria’s are combined and the total maintenance approach and maintenance planning will be evaluated. This has been done by giving a grade to the used colors and adding all the different aspects together. In this study green gets a 4, if the slider is located in the yellow area the country gets a 3, orange gets 2 and red 1. When adding all the numbers together a final score can be found.

The first section focuses on the general approach and the identification of the elements in need of maintenance. The maintenance strategy, organizations involved and the way the identification of the elements has been done is compared in this section. Noted can be that Portugal scores a bit higher in this part because of the more theoretical approach. The identification of the elements in Belgium is more based on experience and is simplified in a way that the building owner can read the report and maintenance plan without the need of technical knowledge.
Because the Belgian maintenance plan is established to carry out all the work, the maintenance actions mentioned are more limited; little tasks are not mentioned in a detailed manner and are meant to be executed by the building owner. The Portuguese case study has its own maintenance team and so every action can and should be planned and described in the maintenance plan, only for big replacements and repairs the owner needs to carry out the work. The importance of the Portuguese building makes it necessary to have an own maintenance team that is available all the time.

The costs regarding maintenance are calculated in very different ways, while in Belgium cost inventories are used and only and estimation of the costs is reached, the costs in Portugal are calculated in a more detailed way. The price of materials and workhours are calculated and multiplied, for extraordinary maintenance activities the history of maintenance actions with their accompanying prices are used to calculated the current costs. In both cases it will still be an estimation of the needed budget because it is impossible to predict the total costs. Both countries will therefore add a 15% margin to cover the unpredicted maintenance actions.

When looking at how the maintenance plan is put to practice it can be noted that in most cases the maintenance plan that is established by Monument Watch is followed as much as possible. In Portugal where the maintenance plan was the result of a PhD thesis, the plan is not in use because the budget is not sufficient. There is still a reactive maintenance strategy in Portugal, first the elements that are in desperate need of repairing or replacement works are taken care of.

Table 4.7: Summary of the comparison study

<table>
<thead>
<tr>
<th>Maintenance strategy</th>
<th>Organizations</th>
<th>Necessity of having a maintenance plan</th>
<th>Manner of identification of elements</th>
<th>Cultural value of the building/elements</th>
<th>Accessibility of the elements</th>
<th>Availability of a maintenance team</th>
<th>Inspections</th>
<th>Monitoring system used</th>
<th>Spreading of the costs</th>
<th>Manner of calculating the costs</th>
<th>Execution of the plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A summary of the comparison can be found in Table 4.7 where all the rated aspects of maintenance are shown. This table shows on which aspects each country scores better than the other one, green is the best or most efficient answer to the criteria while red represents a solution that is not advisable according to the literature and previous research.

Concluding this comparison of the maintenance of historic buildings in Belgium and Portugal all the aspects are added together, the results can be found in Table 4.8. Belgium scores a little bit higher on most things, it cannot be said that the Belgian maintenance plan is therefore better, the years of experience and the fact that the Portuguese maintenance plan is not put to practice makes the Belgian maintenance plan more effective.

<table>
<thead>
<tr>
<th></th>
<th>BELGIUM</th>
<th>PORTUGAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(= 4)</td>
<td>12 (3)</td>
<td>12 (3)</td>
</tr>
<tr>
<td>(= 3)</td>
<td>12 (4)</td>
<td>6 (2)</td>
</tr>
<tr>
<td>(= 2)</td>
<td>4 (2)</td>
<td>4 (2)</td>
</tr>
<tr>
<td>(= 1)</td>
<td>3 (3)</td>
<td>5 (5)</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 4.8: Concluding comparison
5 CONCLUSIONS

This final chapter concludes this master dissertation and also looks at the future. With the results of this dissertation many more studies can be done.

5.1 Main contributions

The general goal of this project is to compare maintenance in Belgium and Portugal in historic buildings. In order to do so, first the theory of maintenance and maintenance planning is studied and analyzed. This way more information has been gathered.

Maintenance is defined as the combination of all technical and associated administrative actions during the service life to retain a building or its parts in a state in which it can perform its required functions. (ISO 15686.1, 2011) A good and effective maintenance strategy has many benefits and can be both planned and unplanned. Unplanned maintenance is also known as reactive or emergency maintenance and will only act to restore the building or its elements after a failure. Planned maintenance can be further divided into preventive maintenance and planned corrective maintenance. The importance of a planned maintenance has both long term and short term effects; the physical characteristics of the building will be preserved which is important when the building has a cultural value. there will also be fewer breakdowns and the improved condition of the building gives a positive effect to the users, resulting in lower staff turnover, better customer relations and public image. An effective maintenance plan will also reduce the maintenance costs; having preventive maintenance could reduce the costs at about two thirds than when no maintenance has been done and majors repairs are needed to keep the building in a good condition.

In Europe, the maintenance sector is marked by two important periods in time. The period after the Second World War saw the introduction of economic and durability principles that influenced the decision of demolition or conservation or buildings. This period is followed by a more economic stable period with a stagnation in the population growth. The construction industry embraced maintenance and rehabilitation in 1964, with the Venice Charter the maintenance industry finally got some legislation guidance. This Charter outlines the basic tenets of what is now accepted to be an appropriate approach with maintenance in historical buildings. Since this charter many standards are created and organizations are founded to help the heritage owners and to put maintenance in historic buildings in the spotlights.
In Belgium it is not obligated by law to have a maintenance plan but the government does support heritage owners financially when they have a maintenance plan. This is sadly for most owners the main reason to create and follow a maintenance plan.

The maintenance approach in Portugal is based on an empirical approach because of the lack of budget, knowledge and technical models and the lack of support tools to help planning. There is also no legislation that obliges owners to make a maintenance plan. A new building regulation, that is still under discussion, introduces the obligation on an inspection and maintenance building manual as part of the execution project.

The best way to maintain a building is by following a maintenance plan. The starting point of this maintenance plan is collecting the information and the determination of the strategy that fits the building the best. After this the maintenance actions needed are known and the planning can be started. Inspections are a big part of these maintenance actions and should be performed on a regular basis. An important factor of the maintenance plan are the costs of the maintenance actions, this is not always easy to determine and several methods can be used.

This master dissertation focusses on the maintenance plan of historical buildings in Belgium and Portugal. In Belgium the organization Monument Watch, based on the Dutch original success story, establishes maintenance plans for its subscribers and performs annual inspections. This organization has a lot of experience regarding maintenance in heritage buildings and provides this study with three buildings. In Portugal the Jeronimos Monastery has been chosen for the comparison study. For this important cultural monument a maintenance plan has been established as a result of a PhD thesis. The comparison can be divided in three phases, the preliminary phases; where information about the building is collected followed by the comparison phase. This second phase focusses on three different aspects of maintenance. First of all the general approach of maintenance and maintenance planning will be discussed together with the identification of the elements in need of maintenance and the determination of their physical condition. Secondly the maintenance actions are discussed and finally the costs and calculation methods are being described and analyzed. This comparison phase is followed by a conclusion and discussion phase in which all the previous information will be put together and a final conclusion is formed.

It can be noted that the Belgian organization Monument Watch has a lot of experience and does not work with an own maintenance team. Every task needs to be outsourced and the heritage owner needs to find the right contractor for every job. Therefore the maintenance plan of the Belgian case studies is made in a way that it is very easy to be understood by the building owners who mostly do not have a technical knowledge. This is not the case in Portugal, the Jeronimos monastery has an own
maintenance team available so the maintenance plan is more detailed. Especially the identification is more detailed than in Belgium where the coding system is very simple and easy to understand. In Portugal every element gets its own specific code for which a manual is needed. This however prevents confusion and mistakes because every element is described unambiguously. Another remarkable aspect of the Portuguese maintenance plan is the attention that is given to the cultural significance of the elements and the building in general. The cultural significance of an element is used to determine the priority of the maintenance activities. These aspects are getting less attention in Belgium where the priority is determined using the recommendations of the inspection report and the experience of the organization. The third aspect that has been compared are the costs and how they are calculated. Both countries use different methods to do this. Because Monument Watch does not execute any actions the costs are just a rough estimation. Portugal on the other hand calculates the costs in a more detailed way, dividing the works into two categories and calculating the costs based on the materials and people used and on previous maintenance works. Concluded can be that the Belgian maintenance approach and maintenance plan is more based on experience while the Portuguese one is purely based on theory. This is one of the main reasons why the Belgian plan is more effective than the Portuguese one, however it is difficult to compare both countries because the buildings have a different cultural value and the Portuguese maintenance plan is not put into practice.

5.2 Future developments

One can conclude that maintenance is still a topic that needs and deserves much more attention. In some countries, regulations have been created and organizations are founded to put this maintenance in the spotlight but still a lot of legislation is missing. With all the benefits of a good and effective maintenance plan there should be more pressure on the building owners by the government. This study also showed that it is not easy to establish an action map or a maintenance plan template that can be used for all buildings. Every building is different and has different needs.

In the future more research can be done in the areas of why there is a reactive maintenance strategy going on in Portugal and how this can be changed into a more preventive one. Also the maintenance in other countries in or outside Europe could be compared to both Portugal and Belgium so see if there are other differences in the maintenance approach than found in this master dissertation. It could be also very interesting to see if the approach of Monument Watch can be used in a non-historic building, this way a general maintenance plan could be established that is compatible with all kinds of buildings.
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7 APPENDICES

7.1 Appendix 1. Example of the Belgian maintenance plan – Alexian monastery
### General remarks

This maintenance plan is based on the recommendations of Monument Watch Antwerp (Inspection report A-45/11117/2012/6).

### Counseling – studies - review

<table>
<thead>
<tr>
<th>Description</th>
<th>Measuring code</th>
<th>Quantity</th>
<th>Frequency</th>
<th>Price per Unit</th>
<th>Total cost/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>gen</strong> Subscription Monument Watch Province Antwerp</td>
<td>s</td>
<td>1</td>
<td>annually</td>
<td>33,00</td>
<td>33,00</td>
</tr>
<tr>
<td><strong>gen</strong> Structural inspections Monument Watch Province Antwerp with the particular attention to the damage by wood-boring insects and cracking</td>
<td>eq h</td>
<td>16</td>
<td>biennially</td>
<td>22,47</td>
<td>359,52</td>
</tr>
<tr>
<td><strong>5.6.1.</strong> Investigation of the discoloration under the stained glass windows and the salt damage in the courtyard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5.6.2.</strong> Wing [4] Urge the neighbor to restore the water drainage to avoid further consequential damages</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>8.1.</strong> Annual inspection and maintenance of the lighting conductor installation by an authorized firm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintenance contract with specialized firm</td>
</tr>
</tbody>
</table>

**gen** = general, **s** = sum over all, **eq** = expected quantity, **p** = piece, **h** = hour
<table>
<thead>
<tr>
<th>gen</th>
<th>Construction site – preparatory work</th>
<th>8, 5% of the construction cost for the works listed below, depending on type of work to be carried out that year</th>
</tr>
</thead>
<tbody>
<tr>
<td>gen</td>
<td>Site Installation</td>
<td>612.00</td>
</tr>
<tr>
<td>gen</td>
<td>Site materials (scaffolding, steeplejack, ...)</td>
<td>4.200.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.1.2.</th>
<th>Roof - works</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>wing</td>
<td>Durable repair of the defects in the roof coverings - restoring the connection of some slates</td>
<td>s 1 once</td>
</tr>
<tr>
<td>[2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>gen</td>
<td>Renewing of all the coping lead including renewing the connection of the ridge brackets with stainless steel screws</td>
<td>eq m 150 once</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1.1.2.</th>
<th>Roof structure and attic</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Attic</td>
<td>Placing a ladder to the tower</td>
<td>eq p 1 once</td>
</tr>
<tr>
<td>[2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attic</td>
<td>Applying new safe walkways</td>
<td>vh m 22 once</td>
</tr>
<tr>
<td>[2]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attic</td>
<td>Dusting the attic space and removal of construction waste</td>
<td>s 1 once</td>
</tr>
<tr>
<td>[2]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Masonry                         |                                                                                                         |                                                                                     |
| Exterior joinery                |                                                                                                         |                                                                                     |
| Painting & finishes             |                                                                                                         |                                                                                     |

* gen = general, s = sum over all, eq = expected quantity, p = piece, h = hour
<table>
<thead>
<tr>
<th>Subtotal of the maintenance budget</th>
<th>7,845,00</th>
<th>34,271,65</th>
<th>1,904,63</th>
<th>102,952,15</th>
<th>82,574,38</th>
<th>392,52</th>
</tr>
</thead>
<tbody>
<tr>
<td>15% margin for unforeseen works</td>
<td>1,176,75</td>
<td>5,140,75</td>
<td>286,69</td>
<td>15,442,62</td>
<td>12,366,16</td>
<td>58,09</td>
</tr>
<tr>
<td>Total per year in €</td>
<td>9,021,75</td>
<td>39,412,39</td>
<td>2,191,32</td>
<td>118,394,77</td>
<td>94,960,53</td>
<td>451,46</td>
</tr>
</tbody>
</table>

Total budget for 6 years (taxes not included): 264,431,36 €
## Appendix 2. Maintenance plan for Jeronimos Monastery

<table>
<thead>
<tr>
<th>Code</th>
<th>Area</th>
<th>Code</th>
<th>Code</th>
<th>Code</th>
<th>Code</th>
<th>Code</th>
<th>Location</th>
<th>Inspection</th>
<th>Periodicity</th>
<th>Frequency</th>
<th>Necessities</th>
<th>Costs per Job</th>
<th>Annual Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>67</td>
<td>Acc</td>
<td>66</td>
<td>church</td>
<td>68</td>
<td>Ads</td>
<td>Roof</td>
<td>Te</td>
<td>Roof tiles</td>
<td>Inspection</td>
<td>x</td>
<td>1 guard</td>
<td>33 02 representative</td>
<td>€ 250.00</td>
</tr>
<tr>
<td>68</td>
<td>Ads</td>
<td>69</td>
<td>Drainage</td>
<td>70</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>€ 377.00 20 min</td>
</tr>
<tr>
<td>69a</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Insulation</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70a</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70b</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70c</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70d</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70e</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70f</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70g</td>
<td>Antipollution</td>
<td>Ch</td>
<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
</tr>
<tr>
<td>70h</td>
<td>Antipollution</td>
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<td>Wiring</td>
<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
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<tr>
<td>70i</td>
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<td>Inspection</td>
<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
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<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
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<td>Ch</td>
<td>Wiring</td>
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<td>x</td>
<td>1 builder</td>
<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
<td>€ 0.77</td>
<td>1.50</td>
<td>€ 3.66</td>
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<td>54 03 01</td>
<td>/</td>
<td>384 m²</td>
<td>10 min</td>
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<td>33</td>
<td>Maint Entrance</td>
<td>Pav</td>
<td>Terrace</td>
<td>Lg. Floor</td>
<td>Cleaning</td>
<td>x</td>
<td>1 builder + 1 guard</td>
<td>S4 L1 L2 L4 / contract</td>
<td>2,6 B/m²</td>
<td>7 h</td>
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<td>45</td>
<td>Sacraly</td>
<td>Pav</td>
<td>Terrace</td>
<td>Lg. Floor</td>
<td>Cleaning</td>
<td>x</td>
<td>1 builder</td>
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<td>18 ml</td>
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<td>C1</td>
<td>Lath</td>
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<td>x</td>
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<td>Interior Access</td>
<td>C1</td>
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<td>S5 S4 Q1 / acqu. Material</td>
<td>1 un</td>
<td>5 min</td>
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<td>At Lightning rod</td>
<td>Installation</td>
<td>x</td>
<td>1 guard</td>
<td>S1 02 F1 / representative</td>
<td>1 un</td>
<td>5 un</td>
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<td>C1</td>
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<td>Inspection</td>
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<td>C1</td>
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<td>x</td>
<td>/</td>
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<td>/</td>
<td>€ 1,50</td>
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Number of actions: 13 | 6 | 14 | 6 | 4 | 1 | 5 | 4 | total | € 555,40 | € 1,078,00 | € 131,400,00
7.3 Appendix 3. Comparison sheet

**GENERAL APPROACH AND IDENTIFICATION OF THE ELEMENTS**

**MAINTENANCE STRATEGY**

- Preventive
- Reactive

**ORGANIZATIONS**

- Specialized organizations
- None

**MAINTENANCE PLAN**

- Mandatory
- Voluntary

**IDENTIFICATION OF THE ELEMENTS**

- Detailed
- No identification
CULTURAL VALUE OF THE BUILDING/ELEMENTS

- **Important**
- **Not important**

ACCESSIBILITY OF THE ELEMENTS

- **Taken into account**
- **Not mentioned**

MAINTENANCE ACTIONS

MAINTENANCE TEAM

- **Own team**
- **Outsourcing**

INSPECTIONS

- **Regular inspections**
- **Few inspections**

bbbb
CONCLUSION

Effective

Not effective