Eindhoven University of Technology

MASTER

Adaptive reuse of industrial heritage
Empirical building and location factors

Isenia, G.M.

Award date:
2022

Link to publication

Disclaimer
This document contains a student thesis (bachelor's or master's), as authored by a student at Eindhoven University of Technology. Student theses are made available in the TU/e repository upon obtaining the required degree. The grade received is not published on the document as presented in the repository. The required complexity or quality of research of student theses may vary by program, and the required minimum study period may vary in duration.

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 01. Mar. 2025

Adaptive reuse of industrial heritage

Empirical building and location factors

Author: Isenia, G.M. (s434034)

Master program: Architecture, Building and Planning
Track: Urban Systems and Real Estate

Graduation project: 7Z45M0 (45 ECTS)

Year of graduation: 2022

Supervisory team:
Prof. Dr T.A. Arentze
A.W.J. Borgers, MSc
Dr I.V. Ossokina

This master's thesis has been carried out in accordance with the rules of the TU/e Code of Scientific Integrity.

Acknowledgment

I would first like to express my gratitude to my committee chair, Professor Doctor Theo Arentze, for his invaluable guidance and patience. I am also grateful to my other committee members, Associate Professor Aloys Borgers MSc for his critical and constructive comments on earlier drafts of this thesis, and Assistant Professor Doctor Ioulia Ossokina for her expert insight and support.

I am also thankful to my study advisor Josée Pulles for her support and advice during this long journey. I appreciate all the help I got from her.

Lastly, I'd like to mention my family and closest friends. Their moral support and encouragement kept me going and empowered me to persevere through all.

Abstract

The decline of the manufacturing industry since the 1960s has left many historic industrial buildings in the Netherlands abandoned. Many of these buildings are considered heritage due to their cultural, historical, and technical significance. They should therefore be preserved for present and future use. Adaptive reuse has proven an effective strategy to preserve heritage buildings while repurposing them for the present. Adaptive reuse is the process of converting buildings into other, more efficient, and effective uses such that they can better serve user needs and have an extended useful life. Adaptive reuse can deliver multiple benefits to communities and authorities while offering potential opportunities for developers and investors. As empirical research on factors of adaptive reuse is lacking, the study at hand sought to quantitatively assess the effect of building and location variables on the adaptive reuse of historic industrial buildings in the Netherlands.

To attain the study objectives, a literature review combined with a retrospective case-control study was conducted. Twenty independent building and 29 independent location variables, believed to affect adaptive reuse, were derived from literature. Since it wasn't possible to identify all members of the population, a convenience sample was selected from sources publicly available. The sample consisted of 518 historic industrial buildings in the Netherlands of 50 years or more, equally divided into a case group of adaptively reused buildings and a control group of vacant buildings. Data on the independent variables for each sample building were extracted from public secondary sources and stored in an attribute dataset. Data analysis was performed using logistic regression. Besides a null model, three alternative logistic models were successively developed using stepwise selection. The second and third models assessed the effect of the building and location variables on adaptive reuse, respectively. The fourth model assessed the effect of both the building and location variables. Of the 20 building and 29 location variables tested in the fourth model, five building and 12 location variables reached statistical significance and remained in the final model.

The results of the fourth model showed positive effects of increasing building age, listed monument status, increasing surrounding address density, and multi-corner lot on adaptive reuse. In contrast, the variables no window area, small window area, wooden structure, site with industrial zoning, increasing area status score, increasing distance to highway ramp, and fronting a through road showed negative effects on adaptive reuse. The results also suggested a possible effect of the province location of a building on its adaptive reuse. Besides these empirical results, the study produced a table of common types of historic industrial buildings in the Netherlands such as factories, warehouses, and water towers including their typical building and location attributes.

The variable with the largest effect on adaptive reuse was site with industrial zoning, followed by listed monument status and surrounding address density. The positive effect of building age and negative effect of area status score were unexpected because the literature suggested otherwise. Given the nature of the sample, the findings may not generalize to the overall population but will surely prove useful in understanding (some of) the dynamics of industrial heritage adaptive reuse.

Table of Contents

List of figures

1 Introduction

1.1 Background

Industrial heritage has been the center of attention for the last few decades. Historic factories, steel mills, warehouses, and water towers, all tell the story of the work and lives of the people who once worked in the industry. Many of these buildings are considered to have heritage value due to their cultural, historical, and technical significance. This makes them worth preserving for future generations. Industrial heritage buildings are not only objects of social history and expressions of technique but also examples of utilitarian architecture, elements in the urban landscape, and economic properties (Douet, 2012; Oevermann & Mieg, 2014). The reality today is that much of the built industrial heritage in the Netherlands and other parts of the industrialized world is forever lost, and a large part of the remainder is being threatened by vacancy, decay, and demolition. It is therefore that the year 2015 was declared the European Industrial and Technical Heritage Year (40 years since the first European Architectural Heritage Year in 1975) by the European Federation of Associations of Industrial and Technical Heritage to raise awareness of Europe’s industrial and technical heritage. Subsequently, the year 2018 was proclaimed the European Year of Cultural Heritage by the European Union and the Council of Europe to further promote Europe’s cultural heritage, and in particular its industrial cultural heritage.

The decline of the manufacturing industry since the 1960s has left many industrial buildings in the Netherlands abandoned and in disrepair. Technical obsolescence on one hand, and innovation and upscaling of the industry on the other, have only reinforced this process. Especially the region of Twente, known for its former textile industry, was left with many vacant factories decaying and fearing for their future. Because industrial buildings were considered of no architectural merit and seen as baggage from the past, they lacked broad support among the public and policy makers, as opposed to the buildings of the pre-industrial period (Nijhof & Schulte,1994; Nijpels, 1995). As a result, many industrial buildings were demolished to make space for new developments. It wasn’t until the late 1980s, after years of conservation battles, that industrial heritage buildings started to gain the significance they deserve. It was also during this time that adaptive reuse started to gain popularity as a sustainable alternative to demolition and new construction. Adaptive reuse is the process of converting buildings to other, more efficient, and effective uses such that they can better serve user needs and have a useful extended life (Douglas, 2006). The growing practice of adaptive reuse has resulted in many abandoned industrial buildings being reused for a purpose other than the original use and thereby preserved for the future. Still, many historic industrial buildings in the Netherlands are standing vacant and deteriorating while crying out for a new use. As such, they can be seen as a sign of neighborhood decline and a cause for further decline. Exact numbers are lacking, but a national inventory between 2006 and 2008, called The Old Map of the Netherlands and commissioned by the then Government Advisor for Cultural Heritage, revealed that just over 250 industrial buildings were standing vacant or were prone to become vacant in the following 10 years (Harmsen, 2008). By 2011 that number went up when estimates by Statistics Netherlands suggested that between 2011 and 2016, around 500 industrial buildings would become vacant, with more to follow in the next years (Van Leeuwen, 2012). At the time of the study at hand, the National Organization for the Restoration and Redevelopment of Cultural Heritage website (http://www.boei.nl) noted an estimated 500 vacant industrial buildings waiting for a new use.

Adaptive reuse is not a straightforward process. Particularly heritage adaptive reuse presents challenges beyond those faced in new construction. The architectural or historic sensitivity of heritage buildings is one important concern. The proposed conversion could damage or destroy the architectural or historical character of the building if its structure and fabric were to undergo radical changes (Douet, 2012; Douglas, 2006). The likely presence of hazardous materials or inherent defects is another concern (Bullen & Love, 2010; Douglas, 2006; Langston, Wong, Hui, & Shen, 2008). Also, the building may be in such a poor state that it requires extensive repairs and renovation (Douglas, 2006; Bullen & Love, 2010; Oevermann & Mieg, 2014). Another concern is the shortage of skilled and experienced labor that can deliver these projects (Douglas, 2006; Kurul, 2007; Reyers & Mansfield, 2001). And the perceived higher cost of development is often a major barrier for developers and investors (Bullen & Love, 2011a; Dyson, Matthews, & Love, 2015; Loures, 2015). These challenges make it important to consider the factors that contribute to successful adaptive reuse. Douglas (2006) mainly distinguished between the physical, functional, and financial factors. The physical factors relate to the building's capability of adaptation without major disturbance to its structure and fabric. The functional factors have to do with the building's ability to meet occupants' spatial and environmental needs. And the financial factors refer to the financial cost and profit of adaptively reusing the building. Wilkinson, Remøy, and Langston (2014), too, considered the physical and financial factors of adaptive reuse but stressed the locational, legal, environmental, and social aspects too. Bullen and Love (2011a, 2011b), too, regarded these factors as important to adaptive reuse but emphasized market and demand factors as well. While there may be various factors affecting adaptive reuse, ultimately any decision to develop a building is based on financial considerations (Douglas, 2006; Kincaid, 2002). Developers and investors will only invest if they believe they can earn an economic gain (Latham, 2000; McGreal, Adair, Berry, Deddis, & Hirst, 2000). When the gains from adaptive reuse are lower than building anew, the focus will likely be on new builds. Whether an adaptive reuse project will be financially viable or not, is primarily determined by commercial demand (Ball, 1999; Bullen & Love, 2010; Stratton, 2000). And the level of demand is, according to Stratton (2000), influenced by the location rather than the building. Latham (2000) pointed out that market conditions can vary greatly between locations and that an adaptive reuse plan that turns out a commercial success in the city may not be lucrative in the countryside. Similarly, Warner, Groff, and Warner (1980) emphasized inconvenient location as one of the main reasons for lower-than-expected return on investment. Ball (2002), Kincaid (2002), and Shipley et al. (2006a), too, stressed the location as vital to adaptive reuse but considered the building important as well. According to Latham, the better the location, condition, suitability, and appeal of a building, the higher its value (and the lesser the need for building adaptations). Conversely, the poorer these factors are, the lower the value of the building is (and the higher the need for value-creating adaptations). And, as Dyson et al. (2015) noted, "selecting the right building, in the right location, from the outset makes a successful outcome more easily achievable" (p. 52).

While the building and, particularly, the location are considered two of the most important aspects of adaptive reuse, most of the work so far on factors affecting adaptive reuse has focused more on the building (e.g., Gann & Barlow, 1996; Sigsworth & Wilkinson, 1967) and less on the location. Moreover, many of these studies have targeted mostly office buildings (e.g., Geraedts & Van der Voordt, 2003; Kincaid, 2002; Wilkinson, 2014) or have been based on theory or limited case studies (e.g., Bullen & Love, 2011b; Dyson et al., 2015; Wilson, 2010). Therefore, empirical research on factors affecting industrial heritage adaptive reuse, particularly concerning their magnitude and significance, is needed. Ball (2002) is one of the few scholars who has taken a quantitative approach to examining factors affecting the adaptive reuse of industrial buildings. In his survey on the reuse of vacant industrial buildings in Stoke-on-Trent, England, he found among others that the buildings from the postwar period, in good or sound condition, of less than 5000 square feet, on courtyard or island sites, and/or within 8 kilometers of a motorway junction were more often reused than those without these attributes. He also found the canal-side buildings to be very attractive for reuse despite their difficult accessibility. Briggs (2010) studied location factors in the adaptive reuse of old textile mills in North Carolina, United States. He found, among others, that the mills located in areas with historic designation, in areas with affluence, and/or in areas with a young or highly educated population were more likely to undergo adaptive reuse than the mills in areas without these attributes. While these studies suggest that the building and location are indeed important to the adaptive reuse of historic industrial buildings, it remains to be seen whether the findings also apply to other places and types of industrial buildings.

1.2 Problem definition

The decline of the manufacturing industry since the 1960s has left and is leaving much of the built industrial heritage in the Netherlands abandoned and in disrepair. A large part of this heritage has since been demolished. A great part has also been adaptively reused for other purposes. Still, much of the remaining buildings continue to deteriorate while awaiting a new use. Developers and investors will only invest in their adaptive reuse if there are financial gains to be made. The success of adaptive reuse is believed to be mainly affected by factors related to the building and its location. The building factors have received the most attention in the literature, while the location factors have not so much. Also, the magnitude and significance of these factors remain unclear.

1.3 Research relevance

The preservation of industrial heritage in the Netherlands and the rest of the industrialized world has for many decades been a major concern to the national and international community. Due to their cultural, historical, and technical significance, industrial heritage buildings should be preserved for future generations. Industrial heritage buildings give us a glimpse of the past while inspiring us for the time to come. Adaptive reuse has proven an effective strategy to secure the future of these buildings, especially when vacancy, decay, and demolition are on the lurk. Adaptive reuse can deliver social, economic, and environmental benefits to both local communities and authorities while offering potential opportunities for developers and investors.

The study reported here is practically relevant in the sense that it gives greater insight into the adaptive reuse of heritage buildings, especially those of an industrial nature. This contributes to shaping policy on the preservation and management of these historic buildings that make up our towns and cities. Scientifically, the study advances previous work on adaptive reuse by offering new knowledge on building and location factors affecting heritage adaptive reuse. While previous studies mainly relied on interviews and limited case studies, the study reported here used quantitative data to identify determining factors of adaptive reuse. This allows for a deeper understanding of the underlying mechanisms of adaptive reuse and for developing better strategies for it.

1.4 Research objectives

The study entertained two objectives. The first objective was to identify building and location attributes that are regarded in the literature as important factors in industrial heritage adaptive reuse. The second and last objective was to empirically assess the effects of these potential factors on the adaptive reuse of industrial heritage buildings in the Netherlands. Vacant industrial heritage buildings that share the same building and location attributes that have been empirically proven to affect adaptive reuse are considered to have more potential for adaptive reuse than those that don't. This knowledge will facilitate developers and investors seeking adaptive reuse opportunities to locate and identify industrial heritage buildings that are great candidates for future reuse efforts, thereby reducing risk and increasing project viability.

1.5 Research questions

Based on the research objectives, the following research questions and sub-questions were posed:

RQ1. Which building and location attributes are considered in the literature as important factors of industrial heritage adaptive reuse?
    RQ1a. What is industrial heritage and what makes a historic industrial building heritage?
    RQ1b. What types of historic industrial buildings are there in the Netherlands?
    RQ1c. What is adaptive reuse?
    RQ1d. How is adaptive reuse applied to industrial heritage buildings?

RQ2. To what extent do these potential factors empirically affect the adaptive reuse of industrial heritage buildings in the Netherlands?
    RQ2a. Which methods can be used to assess the effects of these potential factors?
    RQ2b. What is the magnitude and significance of the effects?

1.6 Research design

The study aimed to empirically determine building and location factors affecting industrial heritage adaptive reuse in the Netherlands. The dependent variable was binary and defined as whether or not a historic industrial building was adaptively reused. The independent variables were derived from building and location attributes identified in the literature as important factors in industrial heritage adaptive reuse. A case-control design was used to retrospectively assess the effects of the independent variables on the dependent variable. Since it wasn't possible to identify all members of the population of historic industrial buildings in the Netherlands, a convenience sample was selected from sources publicly available. The sample consisted of a case group of adaptively reused buildings and a control group of vacant buildings. The retrospective and non-probability sampling design introduced threats to the internal and external validity of the study due to mainly causality limitations and possible confounding.

Data on the independent variables for each sample building were extracted from public secondary sources and populated in a building and location attribute dataset in Excel. Data analysis was performed using logistic regression. Logistic regression is a classification method for analyzing the effects of one or more independent variables on a binary dependent variable (Agresti, 2007; Simonoff, 2003). Two other binary classification methods available included decision trees and neural networks. Decision trees are tree-based models used for classification and regression. They are known for their simplicity and transparency but tend to overfit (Rokach & Maimon, 2015). Neural networks are a subset of machine learning inspired by the human brain and used to classify and cluster data (Dryfus, 2005). A diagram of the research design is presented in Figure 1.1.

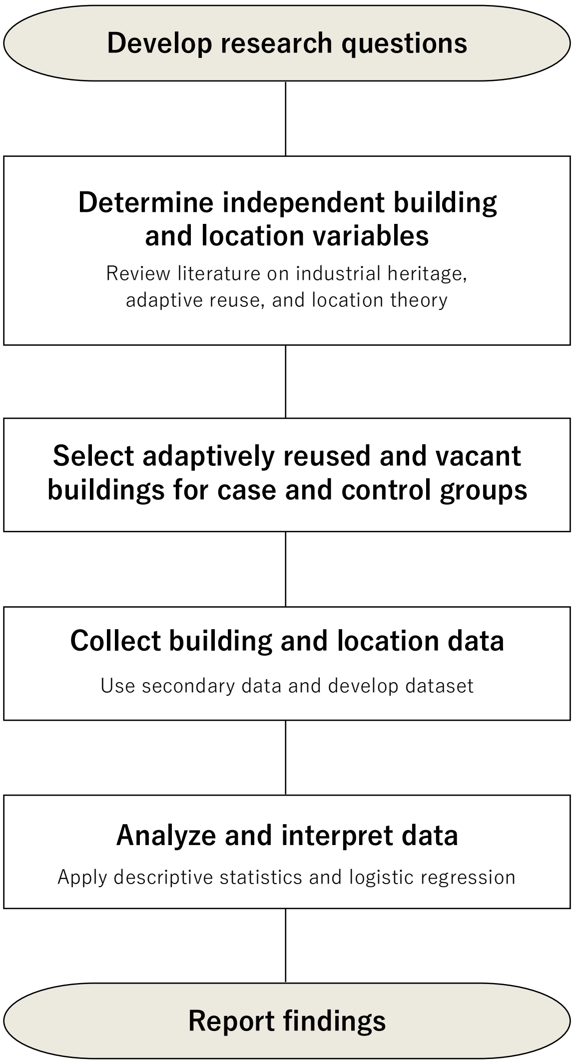


Figure 1.1. Diagram of research design

1.7 Thesis overview

This thesis is organized as follows:

Chapter 1 covers the background of the study, the statement of the research problem, objectives, and questions, and the significance of the study. The chapter also outlines the methodology used to address the research questions.

Chapter 2 provides a review of relevant literature on the emergence and evolution of industrial heritage in general, and particularly in the Netherlands. The chapter presents common types and attributes of historic industrial buildings in the Netherlands and concludes with a look at heritage conservation policy in the Netherlands.

Chapter 3 offers an extensive literature review on industrial heritage adaptive reuse, including its benefits and challenges, its economics, and the stakeholders involved. The chapter further gives an overview of building and location attributes identified in the literature as important factors in industrial heritage adaptive reuse. The chapter also briefly discusses earlier work on location theory to gain a deeper insight into the dynamics of property location in relation to adaptive reuse.

Chapter 4 sets out the methodology used to assess the effects of the literature-based building and location factors on industrial heritage adaptive reuse in the Netherlands. This includes, among others, the research design, sampling procedures, and data collection and analysis methods.

Chapter 5 provides empirical results of the study. The chapter first reports the descriptive statistics and then describes the results of the assumption tests carried out. Lastly, the chapter gives an account of the results of the logistic regression analyses.

Chapter 6 discusses the study results and draws conclusions about the research questions posed. The chapter also provides recommendations for relevant stakeholders and gives an overview of the study’s limitations. The chapter concludes with suggestions for future research.

2 Literature Review (1): Industrial Heritage

This chapter provides an overview of previous literature on industrial heritage needed to respond to the research questions posed. The first section discusses the evolution of industrial heritage in general and in the Netherlands in particular. The second and third sections outline the industries in the Netherlands during the 19th and 20th centuries and the building types within these industries. The fourth section concludes with a look at heritage conservation policy in the Netherlands.

2.1 Evolution and definition

The Industrial Revolution, which started around 1760 in Great Britain and then spread throughout Europe and the United States, has left a great variety of buildings, structures, and landscapes having borne witness to the process of industrialization. While in some places this heritage offers archaeological proof of past activities and technologies, in other places it is still in use, serving societal needs and marking historical continuity. For a long, this type of heritage has been neglected and deprived of cultural meaning. Industrial buildings were usually disfavored because they were too poorly designed and considered of no architectural value, as opposed to the buildings of the pre-industrial period. Industrial buildings were also regarded as too recent to be recognized as heritage. Hewison (1989) defined heritage as “that which a past generation has preserved and handed on to the present and which a significant group of population wishes to hand on to the future” (p. 16). According to Tunbridge and Ashworth (1996), heritage is a “contemporary product shaped from history” (p. 20), conveying that it is subjective and responsive to current needs. If anything, industrial buildings were seen as a threat as they represented a period in which familiar landscapes were transformed, habits disrupted, and established values challenged. And, as some industrial buildings had been frequently altered to keep up with technological and economic changes, they were considered to be lacking in authenticity and originality (Alfrey & Putnam, 1992; Suddards & Hargreaves, 1996; Ten Hallers, 1987). While heritage may have always been around us, awareness and concern for this specific type of heritage only emerged at the beginning of the 1950s in Britain when numerous industrial buildings and landscapes were being lost across the country as a result of the rapid downfall of key industries (Alfrey & Putnam, 1992; Douet, 2012). This reflects the contemporaneity of heritage noted by Tunbridge and Ashworth. Although industrial buildings were not so popular in the conservation battles of the early 1950s, they did initially attract the attention of British historians and archaeologists, who recognized their historical value and their vulnerability to urban renewal and infrastructure development. Industrial heritage buildings perform a vital role in our understanding of the industrial past and the people who were part of it. They are very much of social and cultural importance as part of the record of people’s life and, as such, provide a sense of place, history, and identity. Industrial heritage buildings may also be of scientific and technological value in the history of engineering, manufacturing, and construction, or they may have aesthetic value deriving from their architecture or design (Alfrey & Putnam, 1992; Cossons, 2012; Harrison, 2013). The British historians and archaeologists, who called themselves industrial archaeologists, rapidly organized themselves into regional and national industrial archaeology[1] societies in the 1960s and 1970s to further raise awareness for industrial heritage and its preservation. That concern also spread to North America and later to other parts of the industrialized world, where just as in Britain, industrial archaeology societies emerged to study and promote industrial heritage. For this purpose, numerous attempts have been made to clarify what should or shouldn't be regarded as industrial heritage. In 2003 The International Committee for the Conservation of the Industrial Heritage (TICCIH, 2003) defined industrial heritage as follows:

> Industrial heritage consists of the remains of industrial culture which are of historical, technological, social, architectural or scientific value. These remains consist of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education. (p. 2)

In the Netherlands, it wasn't until the 1980s that industrial heritage, and particularly the built industrial heritage, started to get attention. The many years of negligence were mainly due to gaps in knowledge and understanding of industrial heritage by both policymakers and the general public. The definition of a heritage building was limited and depended largely on the established architectural and aesthetic values. Buildings that evoked unpleasant memories of the industrial period, such as poor working conditions, heavy and dirty work, and smell and noise pollution, were more often destroyed than buildings that recalled the glorious Golden Age (Nijhof & Beernink, 1996). Also, the shortage of land due to high population density had often led directly to the demolition of newly-abandoned industrial buildings in favor of new urban and infrastructure developments (Ten Hallers, 1987). Initially, it was the local and regional conservation groups (since 1984 nationally

Figure 2.1. [D.F. Wouda Steam Pumping Station in Lemmer, built between 1917 and 1918]. Reprinted from *Urbanplan* website, by M. Reiling, 2011, retrieved from https://www.urbanplan.nl/series/woudagemaal.htm/ Copyright 2011 by Maarten Reiling.

Figure 2.2. [Former Van Nelle factory in Rotterdam, built in 1932]. Reprinted from *Janssen en de Kievith Fotografie* website, by M. Janssen, 2013, retrieved from https://www.jkfoto.nl/architectuur-rotterdam/ Copyright 2013 by Janssen en de Kievith Fotografie.

---

[1] The term Industrial archaeology was first used in 1955 by Michael Rix, a historian at the University of Birmingham, when he wrote an article on the Industrial Revolution in Great Britain (Martin, 2009). Industrial archaeology is "a field of study concerned with investigating, surveying, recording, and in some cases, with preserving industrial monuments; it aims, moreover, at assessing significance of these monuments in the context of social and technological history" (Buchanan, 1989, pp. 6-7).

united in the Dutch Federation of Industrial Heritage [FIEN]) that championed the preservation of industrial heritage in the Netherlands, but towards the end of the 1980s also the national government. These efforts led between 1986 and 1993 to a national survey of historic buildings dating from 1850 to 1940, titled Monuments Inventory Project, and a follow-up survey titled Monuments Selection Project. Although these initiatives were not particularly targeted at industrial heritage buildings, they did provide some coverage. Subsequently, in 1992, the government set up a temporary agency called the Project Bureau for Industrial Heritage (PIE) to coordinate further research in this area and promote projects aimed at heritage preservation and management. The high point was the year 1996 when PIE and the Monument Conservation Agency (today the Cultural Heritage Agency of the Netherlands) declared that year as the Dutch Industrial Heritage Year and put industrial heritage on the map. It was a year marked by various activities intended to generate broad interest in industrial heritage among the public and local policymakers. Ever since, industrial heritage has more and more been recognized as an integral part of Dutch cultural history and given monumental importance (Loeff & Beerens, 2013). Perhaps the most important step forward in the recognition of industrial heritage has been the addition of the D.F. Wouda Steam Pumping Station in Lemmer, the largest steam-pumping station ever built in the world and still in operation today, and the former Van Nelle factory (coffee, tea, and tobacco) in Rotterdam to the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage List as World Heritage Sites in 1988 and 2014, respectively. The D.F. Wouda Steam Pumping Station and the Van Nelle Factory are shown in Figure 2.1 (Reiling, 2011) and Figure 2.2 (Janssen, 2013), respectively.

2.2 Industries

For more than a century, industrialization was the prime mover of economic and social change in the Netherlands. During the Dutch Industrial Revolution, which started in the late 19th century, new industries emerged while traditional ones rapidly evolved to keep up with the pace of technology. Depending on their locational needs, the industries established themselves in different parts of the country, as shown in Figure 2.3 (Goossens, 2006). Nijhof (1996) and Nijhof and Beernink (1996) classified the Dutch industries into five categories: infrastructure, trading and finishing, processing and manufacturing, mineral extraction, and public utility. These categories are discussed below.

Infrastructure

The infrastructure industry is one of the oldest industries in the Netherlands and involves the construction and maintenance of transportation and water control works and other infrastructural facilities. Since the beginning, water has played an important role in the development of the Dutch landscape. This is evidenced by the dense network of waterways, the extensive system of locks and sluices, and the unique network of dikes, pumps, and windmills, which originated in the Middle Ages and was further expanded and developed in the 19th and 20th centuries. The 19th century also witnessed the development of the road and railway networks, which were further expanded in the 20th century along with the construction of bridges, tunnels, and railway stations.

Trading and finishing

The trading and finishing industries, too, are among the oldest industries in the Netherlands. These sectors have been key drivers for the Dutch economy and date back far into the past. This is manifested by a large number of warehouses and silos that can still be admired in mercantile cities such as Amsterdam, Rotterdam, and Haarlem. Most of these warehouses were built during the 16th and 17th centuries for the temporary storage of goods (e.g., coffee, tea, sugar, and tobacco) before further processing or shipment to customers. The finishing of the goods took place in small-scale premises in or around the mercantile cities. Noteworthy are the oil mills and paint factories in Zaandam and the breweries and distilleries in Schiedam and Delfshaven, of which only a few exist today. Towards the end of the 18th century, Amsterdam lost its leading position in the world trade network, and consequently many warehouses lost their original function.

Processing and manufacturing

The processing and manufacturing industries have also been important pillars of the Dutch economy. These sectors have made great leaps forward since the industrialization era, particularly the agro-industry. In the 19th century, many agro-processing companies established themselves in areas close to (international) markets, such as the areas along the North Sea coast and the deltas of the major rivers. Most notable are the potato flour and strawboard factories in the provinces of Groningen and Drenthe and the dairy factories in the provinces of Friesland and Overijssel. The textile industry, too, flourished and prospered, with Tilburg and Twente as its centers. After 1960, however, the textile industry went down because of competition overseas and lower local demand. Consequently, many textile factories were left abandoned and desolate. Despite this loss, the 20th century saw the emergence of many new industries such as bioengineering, chemistry, electrotechnology, and graphic technology, which are still thriving today.

Mineral extraction

The extractive industry, too, is an old industry in the Netherlands and consists of any operation that removes metals, minerals, and aggregates from the earth. Examples of extractive industries include mining and oil and gas extraction. Mining already started in the Middle Ages in the province of Limburg but didn’t become meaningful until the end of the 19th century when mechanization was introduced. The rising demand for coal by the ongoing industrialization and the hold-up in the supply of foreign coal during World War I made larger exploitation necessary. After World War II, however, the coal industry was increasingly threatened by the rise of liquid fuels and the increasing import of cheaper coal, which resulted in the closure of the Limburg mines between 1962 and 1974. Today only a handful of mining buildings exist as relics of the past. The 19th century also witnessed the upscaling of the peat industry as a response to the increasing energy demand resulting from the ongoing industrialization and population growth. Many peat factories emerged on the peatlands in the provinces of Groningen and Drenthe. The boom of the peat industry was short-lived as peat was replaced by coal, gas, and oil in the first half of the 20th century. This resulted in the closure and demolition of many peat factories.

Public utility

The utility industry involves companies that provide (generation and distribution) essential services such as electricity, gas, sewage, and water. Since industrialization, the utility industry has grown into a large sector of the Dutch economy. To provide the rapidly growing 19th-century cities with lighting, coal-gas plants emerged in the first half of that century. These plants were initially privately owned but around 1900, they were municipally controlled to better control the smell and reduce the price. In the 1880s when gas lighting began to lose ground in favor of electric lighting, power plants began to spring up all over the country. By 1900, every major city had its own municipal power plant. With the arrival of the cheaper natural gas in the 1950s, the older coal-gas plants were forced to close their doors. And to combat the many epidemics caused by contaminated water, sewerages and water plants emerged after 1850 in many towns and cities across the country.

	REGION	INDUSTRY
🟩	Betuwe, Top of North Holand	Canning
🟨	Friesland, West Overijssel	Dairy
🟩	East Drenthe, Groningen, Northeast Overijssel	Potato flour and strawboard
●	Hillegom, Lisse	Flower bulb cultivation
🟥	Limburg	Mining
🟪	West North Brabant, Zeeland	Sugar refinement
▨	Drenthe, Friesland, Groningen	Peat
🟨	Rivers area	Brick-making
●	Amsterdam, Rotterdam	Trade
●	Delft, Schiedam	Brewing and distilling
●	Enschede, Tilburg	Textile
●	Utrecht	Metal
▭	Zaan district	Paint, wood, and seed-oil
▥	Zuyder Zee area	Fish smoking
▥	Southeast Utrecht	Tobacco

Figure 2.3. Industries in the Netherlands. Adapted from *Industrieel erfgoed - tijdelijk definiëren: Een beslissingsondersteunend model Tijdelijke verhuur industrieel erfgoed (BTI-model) voor de ontwikkelaar* (p. 19), by N. Goossens, 2006, retrieved from https://research.tue.nl/en/studentTheses/industrieel-erfgoed-tijdelijkheid-definiëren/ Copyright 2006 by Noortje Goossens.

2.3 Building types

The variety of industries that existed and emerged in the Netherlands in the 19th and 20th centuries required different types of buildings in different locations. As the industries kept growing, their spatial and locational requirements kept changing. Therefore, the buildings housing these industries were often adapted while new buildings were constructed elsewhere to meet the changing needs of the industries. The following subsections discuss three common types of historic industrial buildings in the Netherlands: factories, warehouses, and water towers.

2.3.1 Factories

Before the Industrial Revolution, there were (almost) no large industries in the Netherlands. Production was handicraft and took place at home or in small house-style buildings. These buildings had a simple design and were strongly influenced by local conditions. Their location was largely determined by access to transport routes and energy sources such as wind and water. Once the Industrial Revolution got underway, productive work moved from homes into factories. The first factories ever built in the world emerged in 18th century Britain for the mechanization of the textile industry. Large factory buildings of four to six stories high, driven first by hydropower and later by steam power, were erected on British soil. In the first half of the 19th century, the factory system slowly spread to the Netherlands but was limited to a few industries such as textile, diamond cutting, and sugar refining. As more and more industries switched to the factory system in the second half of the 19th and early 20th centuries, more types and styles of factory buildings emerged (Dekkers & Wiersma, 1986; Nijhof, 1985). Nijhof (1985) classified the historic factory buildings in the Netherlands into three types: early 19th-century factory buildings, classic factory buildings, and modern factory buildings. These types of factory buildings are discussed further below.

Early 19th-century factory buildings (1820-1860)

The early 19th-century factory buildings emerged in the 1820s and featured a sober design with ornaments derived from classical antiquity at the most. They were timber-framed with a tight rectangular shape and symmetrical façade. The buildings further featured a side extension for the boiler room and a chimney. Most of the early 19th-century factory buildings were concentrated in walled cities. Polluting and space-consuming factories were located as much as possible outside the city walls along arterial roads and canals leading out of the city. The early 19th-century factory buildings have practically disappeared.

Classic factory buildings (1860-1920)

The classic factory buildings emerged in the 1860s and differed greatly from their predecessors. Nijhof (1985) classified the classic factory buildings into multistory, single-story, and high bay classic factory buildings. These subtypes still exist today and are discussed below.

The multistory classic factory buildings feature a sober or monumental design in neoclassical, neo-Renaissance, or neo-Romanesque style. They have a tight rectangular shape, cast iron column structure with brick cladding, and rows of windows in a symmetrical façade, as shown in Figure 2.4 (De Koning, 1996). Some of these factory buildings also have a water tower that used to serve as a

Figure 2.4. [Former C. Mommers & Co. wool factory in Tilburg, built in 1885]. Adapted from *Cultural Heritage Agency* website, by J.P. de Koning, 1996, retrieved from https://beeldbank .cultureelerfgoed.nl/ Licensed under a Creative Commons Attribution-ShareAlike 3.0 Generic license, http://creativecommons.org/licenses/by-sa/3.0/

Figure 2.5. [Interior of the former Herman Driessen steam weaving mill in Aalten, built in 1893]. Adapted from *Cultural Heritage Agency* website, by IJ. Heins, 2002, retrieved from https://beeldbank.cultureelerfgoed.nl/ Licensed under a Creative Commons Attribution-ShareAlike 3.0 Generic license, http://creativecommons.org/licenses/by-sa/3.0/

water reserve for fire-fighting or production processes. The multistory classic factory buildings were mostly used for light and medium industries, such as spinning and weaving, where the vertical transport of raw materials and finished goods wasn't too problematic and the load could be evenly distributed over the floors. The multistory classic buildings were until well after World War I mostly built in densely populated areas. This had to do with less land area being required when building upwards while spreading the needed space across the floors. The vertical transport of people and goods can, however, be time-consuming, and the usable floor space can be significantly reduced due to staircases, elevators, and columns.

The single-story classic factory buildings were built after 1870 and were mostly used in the weaving industry. They feature a steel frame with a glazed sawtooth roof, as shown in Figure 2.5 (Heins, 2002). This allows for longer spans and better daylighting and ventilation. The single-story classic factory buildings also have high floor loadings but are less space-efficient due to the large footprint. The high bay classic factory buildings emerged at the end of the 19th century to accommodate heavy industries, such as casting and metalworking. The buildings feature a cast iron column structure or steel frame with a brick facade. The facade was initially richly decorated but was later kept sober to expose the building's structure. The high bay classic factory buildings are one story high and have a large overhead space that was used for operating cranes. The buildings further have one or multiple halls. The ones with one hall generally have a flat roof fitted with windows for daylighting and ventilation. Those with multiple halls have a high nave in the middle and lower aisles on the sides, as shown in Figure 2.6 (De Roeck, 2016).

Modern factory buildings (1900-1960)

The modern factory buildings owe their existence to the introduction of reinforced concrete at the end of the 19th century. Reinforced concrete made new construction techniques available due to its compressive strength and durability. It was now possible to create larger spans and achieve higher building heights than before with cast iron. The modern factory buildings from the beginning of the 20th century were built with a multistory concrete frame and clad with brick. After 1910, the buildings were built without the brick cladding mainly due to influences of modern architecture styles such as New Objectivity or Neues Bauen. An example is shown in Figure 2.7 (Van Onna,

Figure 2.6. [De Ijzergieterij, a former iron foundry at the Piushaven in Tilburg, built in 1900]. Adapted from *Mijn Piushaven* website, by F. de Roeck, 2016, retrieved from https://mijnpiushaven.nl/bouw-ijzergieterij-elf-maanden-later/ Copyright 2016 by Freddie de Roeck.

Figure 2.7. [The White Lady, a former light bulb factory in Eindhoven, built in 1926]. Reprinted from *Herbestemming.nu* website, by N. van Onna, 2006, retrieved from https://www.herbestemming.nu/projecten/de-witte-dame-eindhoven/ Copyright 2006 by Norbert van Onna.

2006). In the period between the wars, the construction of multistory factory buildings declined sharply in favor of single-story large-span factory buildings. This trend was mainly prompted by the development of large industrial zones outside the city bounds, which made it possible for industries to build large and cheap. The factory buildings of the interbellum were constructed with concrete or steel frames and clad with brick. After 1945, this trend continued to hold till the late 1960s, after which the flat-roofed metal buildings that dominate the industrial landscape today appeared.

Factory location

Until the early 1900s, there was no national policy on industrial location. Non-extractive and non-water-dependent industries established themselves as much as possible in old town and city centers. Behind the densely-built frontage of narrow streets and the ribbon development along arterial roads, numerous factory buildings appeared. Water-dependent industries were located along canals and rivers, while polluting and space-consuming industries were kept as much as possible outside the city walls. After 1874 when the city walls came down, several industries established themselves in the former fortification areas, especially the gas-producing industries. With the completion of the railroad before the turn of the century, many fast-growing industries left the built-up towns and cities and moved to open fields along the railroad tracks. Also, the introduction of the automobile in the Netherlands at the beginning of the 20th century spurred the further development of the road network, opening up more areas outside of towns and cities. In 1902, the first Housing Act came into force, and in the years after, requirements for systematic spatial planning were established. The concept of the industrial zone was introduced, and with the rollout of the electricity grid and the further development of the road network since the 1920s, industries got greater freedom of location choice. Locations along major roads and highways became more and more popular for industries to locate, as opposed to locations along the railways. The emerging heavy metal and petrochemical industries established themselves as close as possible to the newly developed deep-water ports, such as those in Rotterdam and Ijmuiden. In the post-war decades, the new industrial zones were, at the government’s urging, exclusively built on the peripheries of cities along beltways and highway intersections. A summary of the types and attributes of the factory buildings discussed in this subsection is provided in Table 2.1.

2.3.2 Warehouses

The warehouses in the Netherlands date back very far in history. The earlier ones were mostly built in Amsterdam and, to a lesser degree, in other mercantile cities such as Haarlem and The Hague. Many of the earliest warehouses in these cities managed to withstand the centuries, as opposed to the warehouses built in other parts of the country. Bonke (2011) classified the historic warehouses in the Netherlands into traditional warehouses, dating from the 16th until the 19th century, and modern warehouses, dating from 1876 and later. Both types are discussed below.

Traditional warehouses (1500-1876)

The traditional warehouses most likely originate from the canalside houses of medieval merchants who used the basement and attic of the houses to store their goods. Due to a lack of storage space

Figure 2.8. [Former warehouses at Brouwersgracht in Amsterdam, built in the 17th century]. Adapted from *Holland in Pixels* website, by B.B. van Dam, 2010, retrieved from https://hollandinpixels.photoshelter.com/image /I0000C0r7G38zwds/ Copyright 2016 by Holland in Pixels.

Figure 2.9. [Former De Zwijger warehouse in Amsterdam, built in 1934]. Adapted from from *Architectenbureau J. van Stigt* website, by J. van Stigt, 2018, retrieved from https://burovanstigt.nl/product/pakhuis-de-zwijger-2/ Copyright 2018 by Architectenbureau J. van Stigt.

and limited floor load capacity, there was a need for a more solid building with multiple floors for storage. By reinforcing the structure and adding more floors to the merchant house, the traditional warehouse probably came into being. The traditional warehouses were originally built of wood but after the many devasting city fires, they had to be built with brick load-bearing walls. The traditional warehouses are generally 4 to 7 stories high with an average floor height of 2,5 meters. They have a narrow and deep floor plan of about 6 by 45 meters. Most traditional warehouses have a functional design, without any frills or decorations. They are further characterized by a symmetrical façade with shutters one above the other, which are flanked by arched windows. The traditional warehouses from the end of the 16th century till the half of the 17th century are low and wide with a trapezoidal gable. Those from around the middle of the 17th century are higher and narrower with a spout gable, crowned with a triangular or semi-circular fronton, as shown in Figure 2.8 (Van Dam, 2010). The warehouses from the 18th century are even higher and narrower with only the spout gable, and those from the end of the 18th to the 19th century have exclusively a cornice gable.

Modern warehouses (1876-1968)

The modern warehouses owe their origin to the arrival of the steamship and the freight train at the end of the 19th century, which led to an increase in the movement of goods. Because the storage companies had different accommodation needs than the transport companies, different types of warehouses emerged. The storage companies housed themselves in large multistory buildings with sufficient space for storage, sampling, weighing, and packaging. The transport companies, which were merely oriented towards fast cargo handling, housed themselves in single-story buildings to minimize vertical transport. The late 19th-century modern warehouses were built with cast-iron columns and beams and brick load-bearing walls. With the development of deep-water quays and mobile cranes, many of these warehouses were then erected along the quays (instead of the canals) to speed up loading and unloading. At the beginning of the 20th century, when reinforced concrete was introduced, warehouse construction entered a new period of development. The early 20th-century warehouses were built with concrete frames and masonry infill or built completely in concrete, as shown in Figure 2.9 (Van Stigt, 2018). By 1950, when the first forklifts appeared, the warehouses were built higher and wider with steel frames and brick cladding. Forklifts allowed for faster and more efficient movement of goods inside the warehouse. On average, the warehouses built in the 1950s and 1960s measure 25 to 30 meters wide and 150 to 200 meters long. A summary of the types and attributes of the warehouses discussed in this subsection is provided in Table 2.1.

2.3.3 Water towers

Water towers emerged in the Netherlands in the 1830s and have since been visible elements in urban and rural landscapes. Their dominant appearance has made them stand out from the rest. Van der Veen (1989, 1994) classified the historic water towers in the Netherlands into railway water towers, industry water towers, and drinking water towers. These types are discussed below.

Railway water towers (1836-1854)

The railway water towers were mostly built between 1836 and 1854 and were used to supply water to steam locomotives. These water towers were often located near train stations along the tracks. Due to their small size and sober design, they hardly stood out. Apart from a few examples, the railway water towers were all destroyed after steam traction disappeared.

Industry water towers (1854-1970)

The industry water towers emerged after 1854 and were mostly used as a water reserve for fire-fighting in the textile industries and production processes in the paper and gas industries. The water towers for production processes were often built attached to a factory building.

Figure 2.10. [Former water tower along the Wantij in Dordrecht, built in 1882]. Reprinted from *Watertorens in Nederland* website, by J. van Zegveld, 2012, retrieved from http://www.watertorensnederland.nl/watertorens/dordrecht_wantij/dordrecht_wantij.html Copyright 2012 by Johan van Zegveld.

Figure 2.11. [Former water tower in Groningen, built in 1908]. Reprinted from *Wikipedia* website, by M. Verbeek, 2015, retrieved from https://en.wikipedia.org/wiki/User:Michielverbeek/Fotoalbum-Groningen/ Licensed under a Creative Commons Attribution-ShareAlike 4.0 Generic license.

Figure 2.13. [Former Belcrum water tower in Breda, built in 1935]. Reprinted from *Watertorens in Nederland* website, by J. van Zegveld, 2013, retrieved from http://www.watertorensnederland.nl/watertorens/breda_speelhuislaan/breda_speelhuislaan.html/ Copyright 2013 by Johan van Zegveld.

Drinking water towers (1854-1970)

The drinking water towers, too, emerged after 1854 to supply drinking water to households and firms. These water towers were first built in major cities and, after 1900, across the whole country. As freestanding structures, the drinking water towers were erected where they could best collect the groundwater and distribute it to the end consumers. Due to their size and striking design, they still enjoy great popularity. The drinking water towers were the most built of all water towers.

Construction and design

The construction of the water towers is, in essence, the same for all types. It consists of a closed or open structure that supports a water tank that is placed at a height enough to pressurize the water distribution system. Depending on the required water pressure, the towers were usually erected 20 to 35 meters high and sometimes even up to 60 meters, with a diameter varying between 10 and 25 meters. The water towers in rural areas were generally built tall and slender, while those in urban areas were built low and squat. The water towers from the 19th century are usually square or rectangular and have a closed brick structure that is punctured with openings here and there for doors and windows. The water towers from the 20th century generally have a lighter and slimmer design than those from the 19th century and are square or circular. They also usually have a concrete or steel frame structure, as shown in Figure 2.11 (Verbeek, 2015). The structure is sometimes clad with brick, which defines the exterior of the tower but has no structural meaning.

The design of the water towers almost always includes features of architectural styles common during the design phase. The design of the earliest water towers was initially derived from examples in the industry and was typically eclectic, that is, with elements from different architectural styles, as shown in Figure 2.10 (Van Zegveld, 2012). Around 1880, however, the sober Neo-Romanesque style became dominant, and in the 20th century, several architectural styles followed each other, from eclecticism to Art Deco to New Objectivity to Amsterdam School. An example is shown in Figure 2.12 (Van Zegveld, 2013). The succession of architectural styles in building design has resulted in an extensive and varied portfolio of water towers in the Netherlands. A summary of the types and attributes of the water towers discussed in this subsection is provided in Table 2.1.

Table 2.1

Historic industrial building types

Building type	Period	Building attributes	Location attributes
Factories			
Early 19th-century factory building (disappeared)	1820-1860	Sober design with symmetrical façade, occasionally with classical ornaments Rectangular wood frame structure Compact layout with chimney and side extension for boiler room Easy expansion potential	In old towns and city centers behind densely built frontages and ribbon development Water-dependent industries along canals and rivers and polluting and space-consuming industries outside city walls along arterial roads

Classic factory building – Multistory	1860-1870	Compact layout with multiple floors Sober or monumental design with symmetrical façade Cast iron support structure with brick cladding, fitted with rows of windows	In old towns and city centers behind densely built frontages and ribbon development Water-dependent industries along canals and rivers and polluting and space-consuming industries outside city walls along arterial roads Site with limited expansion potential
Classic factory building – One-story	1870-1920	Spacious single-floor layout Steel frame construction with glazed shed roof and brick cladding Long span and high floor loading Easy expansion potential	In former fortification areas around city cores and in open fields along railways Large site with expansion potential
Classic factory building – High bay	1900-1920	Steel frame or cast-iron support structure with brick façade Single-hall design with glazed flat roof or multiple-hall design with a high middle nave, flanked by lower aisles Long span with large overhead space High structural strength and floor load	In former fortification areas around city cores and in open fields along railways Large site with expansion potential
Modern factory building	1900-1930	Spacious layout with multiple floors New Objectivity style Concrete frame construction with brick cladding or full concrete structure with large windows Long span with high floor loading	In open fields along railways Outside towns and city centers along major roads and highways Large site with expansion potential
	1930-1960	Large single-floor layout Steel frame construction with brick cladding or full concrete structure Long span with high floor loading Easy expansion potential	Outside town and city centers along major roads, in industrial zones along beltways and highway intersections, or near deepwater ports Large site with expansion potential
Warehouses			
Traditional warehouse	1500-1876	Sober and functional design Symmetrical façade with shutters one above the other, flanked by arched windows Initially wooden structure and walls, later load-bearing brick walls Mid-rise (4-7 stories) with a narrow and deep floor plan of 6 by 45 m Column-free layout with high floor loading	In mercantile (port) cities along canals and small streets Accessibility by road and water A compact site without expansion potential
Modern warehouse	1876-1900	Large single or multistory design Cast iron support structure with brick load-bearing walls High floor loading	In mercantile port cities along quays Accessibility by rail, road, and water Large site with expansion potential
	1900-1950	Large single or multistory design Concrete frame with masonry infill or full concrete structure High floor loading	In mercantile port cities along quays Accessibility by rail, road, and water Large site with expansion potential

	1950-1968	Large design with widths of 25 to 30 m and depths of 150 to 200 m Steel frame with brick cladding Long span and high floor loading	In mercantile port cities (along quays) Accessibility by rail, road, and water Large site with expansion potential
Water towers			
19th-century railway water tower (disappeared)	1836-1854	Small inconspicuous design	Near train stations along the tracks
19th-century industry water tower	1854-1970	Attached to a factory building	On industrial sites
19th-century drinking water tower	1854-1900	Closed brick structure in a square or rectangular shape Low and squat in eclectic or Neo-Romanesque style Varying heights of 20 to 35 m and varying widths of 10 to 25 m	In major cities
20th-century drinking water tower	1900-1970	Concrete or steel frame construction in square or circular shape Low and squat in urban areas or tall and slender in rural areas Various architectural styles Varying heights of 20 to 60 m and varying widths of 10 to 25 m	Across the whole country

2.4 Preservation and conservation

The element of potential or real threat to heritage (of destruction, loss, or decay) has linked industrial heritage buildings in the Netherlands since the 1980s with movements advocating for the preservation and conservation of buildings. Preservation and conservation are often taken as being synonymous, but the former is about arresting or retarding the deterioration of a building (through maintenance and repair), while the latter goes beyond preservation by including any action to secure the survival of the building (Douglas, 2006; Feilden, 2003). Alfrey and Putnam (1992) cited conservation as “the safeguarding of cultural assets, themselves more often seen as relics of a pre-industrial landscape, in a strategy which would enable certain classes of building, site or area to be removed from the normal process of development” (p. 8). According to Stratton (2000), conservation “almost by definition, involves reconciling a desire for continuity with the introduction of new uses, and purist preservation with needs to update the structure and image of a building” (p.9). Changing attitudes towards heritage buildings since the 1990s have caused a shift from pure preservation to conservation. So, while early campaigners fought to save heritage buildings from being razed unnecessarily, their successors are making sure that these buildings will continue to survive.

The main means of identifying and protecting heritage buildings is through heritage listing. Listing aims to ensure that the architectural and historic interest of important buildings is carefully considered before any alterations are agreed upon. The listing gives the buildings legal protection against unauthorized demolition or alteration. Buildings located in designated conservation areas, too, enjoy protection against unauthorized demolition or alteration. In the Netherlands, the Cultural Heritage Agency is responsible for listing monuments (e.g., historic buildings, structures, and sites) of national importance and designating conservation areas, whereas the provincial and local governments are in charge of listing monuments of provincial and local significance, respectively. The protection of national monuments is covered under the Heritage Act 2016, while that of provincial and local monuments is covered under provincial and local ordinances, respectively. At the international level, historic sites considered of outstanding value to humanity may also be designated as World Heritage Sites. This is embodied in the international treaty Convention Concerning the Protection of the World Cultural and Natural Heritage that was adopted by UNESCO in 1972. Once a site is designated as a World Heritage site, its protection and conservation become a concern of the international World Heritage community as a whole.

2.5 Summary

Industrial heritage consists of the remains of an industrial past that are of historical, technological, social, architectural, or scientific value. Industrial heritage reflects the connection between the cultural and natural environment as industrial processes depend(ed) on natural resources and transport links to produce and distribute products. Historic industrial buildings considered industrial heritage should therefore be preserved for present and future use. The historic industrial buildings in the Netherlands of the 19th and 20th centuries, often located in town and city centers, were erected in different types and styles, reflecting the changing industry needs and building techniques in those centuries. For a long time, industrial heritage buildings have been deprived of cultural meaning and protection until the 1980s, after years of conservation battles and regulation reversals.

3 Literature Review (2): Adaptive Reuse

This chapter provides a review of literature on adaptive reuse to respond to the research questions posed. The first section outlines the history of adaptive reuse and the concepts that lie behind its contemporary practice, while the second section discusses its causes and goals. The third and fourth sections examine the interventions and the process and stakeholders in adaptive reuse, respectively. The fifth and sixth sections cover the economics and the benefits and challenges of adaptive reuse, respectively. The seventh and eighth sections conclude with an overview of building and location attributes considered important factors of industrial heritage adaptive reuse.

3.1 Historical background

Adaptive reuse is the process of converting buildings to other, more efficient and effective uses such that they can better serve user needs and have a useful extended life. Adaptive reuse is a type of building adaptation that almost always involves physical changes to the building to accommodate the new use (Douglas, 2006). Section 3.3 further elaborates on these interventions. The adaptation of buildings is anything but new. Already in the Roman Age, buildings were adapted for new uses. A good example is the Italian city of Lucca, where the remains of a Roman amphitheater can be traced throughout the city. In the late Middle Ages, various churches and monasteries lost their original purpose due to religious changes and were converted to other uses. And, during the 17th to 19th centuries, many farm and town buildings were adapted for other uses as a result of the agricultural and industrial changes and the rapid population growth. However, it wasn't until the 1960s that the conversion of buildings, what we now call adaptive reuse, really gained momentum and started being applied on a regular and large scale. This was mainly due to economic reasons and the lack of suitable land in inner urban areas to build on. Also, growing concern about the environment and awareness of the need to revitalize towns and cities besides pleas for the conservation of industrial buildings brought adaptive reuse into mainstream practice (Cunnington, 1988; Douet, 2012; Douglas, 2006). Early efforts were undertaken in U.S. cities such as Boston and San Francisco where the conversion of the Ghirardelli chocolate factory into mixed uses between 1964 and 1968 and the subsequent conversion of the nearby icehouses are often seen as the first successful adaptive reuse developments of industrial heritage buildings (Douet, 2012).

3.2 Causes and goals

Adaptive reuse is usually prompted by the need to ensure that buildings have a beneficial, continuous use and is basically a response to accommodate changing occupancy needs (i.e., change in the purpose or level of activity in a building). As such, adaptive reuse can be considered a tool to prevent or overcome redundancy, obsolescence, and demolition of buildings (Douglas, 2006). Moreover, adaptive reuse is more and more becoming a key driver of urban regeneration (Ball, 1999; Bullen & Love, 2010; Stratton, 2000). Since the last decades of the 20th century, adaptive reuse has also been regarded as a sustainable development strategy (Bullen & Love, 2010; Douet, 2012) and a tool for preserving threatened heritage values of buildings (Ball, 2002; Bullen et al., 2011a; Douet, 2012). The principle of sustainability is manifested in the global movement to recycle buildings and lies, according to Fragner (2012), in “the arguments, structural interventions and architectural designs that leave enough room for future decisions and for uncovering new meanings in situations that we cannot yet foresee” (p.117). As a heritage preservation tool, adaptive reuse can retain the heritage values of buildings threatened by alteration and demolition. As discussed earlier, industrial heritage buildings have evidential value as part of the industrial past. They also have social and cultural value as part of the record of people’s life. Industrial heritage buildings may also be of scientific and technological significance in the history of engineering, manufacturing, and construction, or they may possess aesthetic qualities originating from their architecture or design (Douet, 2012). These values can be easily overlooked in adaptive reuse, especially when commercial interests are at stake (Cosson, 2012; Shipley et al., 2006a).

3.3 Interventions

As noted in Section 3.1, adaptive reuse is a type of building adaptation that usually involves physical changes to a building to facilitate the new use. Building adaptation is any intervention that goes beyond maintenance (i.e., retaining in good order) to change the function, capacity, or performance of a building (Douglas, 2006). These three main branches of building adaptation are shown in Figure 3.1 (Douglas, 2006, p.18). Adaptive reuse always involves a change in function but may also include changes in capacity and performance. A change in function involves a change to the same use, a change to another use, or a change to mixed uses. Converting an underused warehouse into several storage units is a typical example of adaptation to the same use, whereas the conversion of a water tower into office spaces can be typified as an adaptation to another use. A classic example of adaptation to mixed uses is the conversion of a factory building into shops, restaurants, and galleries. Adaptation to another use or mixed uses is, according to Douglas (2006), more

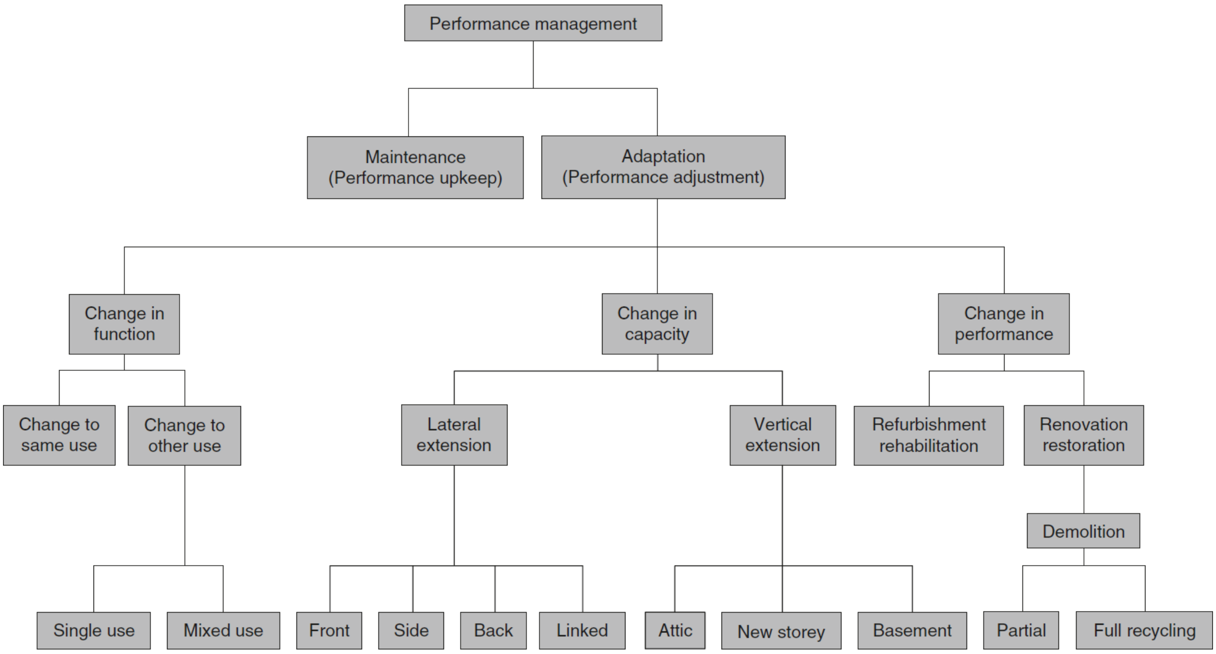


Figure 3.1. The two elements of performance management. Reprinted from *Building interventions* (2nd ed., p. 18), by J. Douglas, 2006, Oxford, England: Elsevier. Copyright 2006 by James Douglas.

troublesome than adaptation to the same use because the new uses may come with functional and spatial requirements other than those of the existing use, often requiring extensive structural alterations. New uses can be for a short or long-term period. Short-term use can be a preferable alternative when finding a long-term use that is financially feasible and sympathetic to the historical character of the building seems impossible at the time (Alfrey & Putnam, 1992; Nijhof & Schulte, 1994). Last, a change in capacity may involve a lateral or vertical expansion, while a change in performance can range from basic preservation (i.e., arrest decay) at one end of the spectrum to demolition and redevelopment at the other end, which is unlikely with listed buildings.

3.3.1 Development combinations

Based on the type and extent of the interventions, Kincaid (2002) proposed six development combinations: (a) change of use through the flexibility of the building as found, (b) change of use through flexibility with minor alterations, (c) change of use adaptation, (d) change of use adaptation with selective demolition, (e) change of use adaptation with extension, and (f) change of use through demolition and redevelopment. These are shown in Figure 3.2 (Kincaid, 2002, p. 55). How far they will go depends, according to Fragner (2012), on the “given situation and available options how much we are able - and willing - to carry over from the past and to absorb in the present; and ... on what the reasons were for bringing the industrial heritage site back to life” (p. 110).

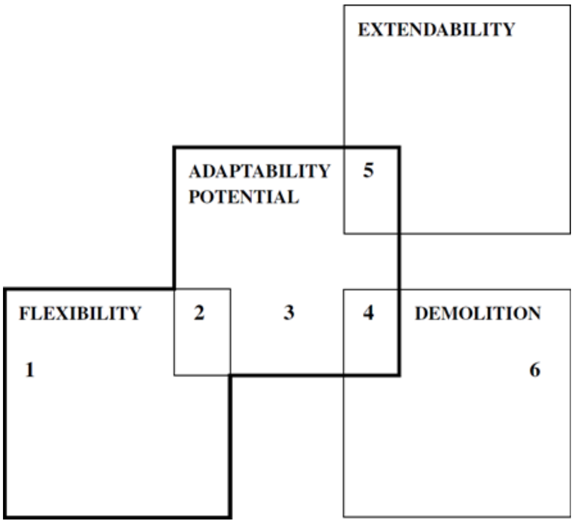


Figure 3.2. Basic development combinations. Reprinted from *Adapting buildings for changing uses: Guidelines for change of use refurbishment* (p. 55), by D. Kincaid, 2002, London, England: Spon Press. Copyright 2002 by David Kincaid.

3.3.2 Conservation principles

The adaptive reuse of heritage buildings is not straightforward. Particularly the historical or architectural sensitivity of heritage buildings is one important concern. Cossons (2012) emphasized that the adaptive reuse of industrial heritage buildings requires “the right level of understanding of intrinsic quality to effect an economically viable transformation that reinforces rather than erodes the fundamental values of the place - the buildings externally and internally, their context and setting” (p. 13). Industrial heritage buildings are not just structures with aesthetic and structural qualities that make them attractive for adaptive reuse but places where history and memories were made. Adherence to conservation ethics can help prevent any proposed intervention from damaging or destroying the historical or architectural character of the building. A key source of guidance when adaptively reusing industrial heritage buildings is the internationally recognized Nizhny Tagil Charter for the Industrial Heritage. It was adopted in 2003 by the TICCIH and lays down nine principles of heritage conservation of which the first seven apply to heritage buildings (2003, p. 5):

I. Conservation of the industrial heritage depends on preserving functional integrity, and interventions to an industrial site should therefore aim to maintain this as far as possible. The value and authenticity of an industrial site may be greatly reduced if machinery or components are removed, or if subsidiary elements which form part of a whole site are destroyed.

II. The conservation of industrial sites requires a thorough knowledge of the purpose or purposes to which they were put, and of the various industrial processes which may have taken place there. These may have changed over time, but all former uses should be examined and assessed.

III. Preservation in situ should always be given priority consideration. Dismantling and relocating a building or structure are only acceptable when the destruction of the site is required by overwhelming economic or social needs.

IV. The adaptation of an industrial site to a new use to ensure its conservation is usually acceptable except in the case of sites of especial historical significance. New uses should respect the significant material and maintain original patterns of circulation and activity, and should be compatible as much as possible with the original or principal use. An area that interprets the former use is recommended.

V. Continuing to adapt and use industrial buildings avoids wasting energy and contributes to sustainable development. Industrial heritage can have an important role in the economic regeneration of decayed or declining areas. The continuity that re-use implies may provide psychological stability for communities facing the sudden end a long-standing sources of employment.

VI. Interventions should be reversible and have a minimal impact. Any unavoidable changes should be documented and significant elements that are removed should be recorded and stored safely. Many industrial processes confer a patina that is integral to the integrity and interest of the site.

VII. Reconstruction, or returning to a previous known state, should be considered an exceptional intervention and one which is only appropriate if it benefits the integrity of the whole site, or in the case of the destruction of a major site by violence.

3.4 Benefits and challenges

The adaptive reuse of industrial heritage buildings presents a series of benefits but also challenges. Some are comparable to those found in the adaptive reuse of conventional buildings, while others are more restricted to heritage buildings. These benefits and challenges can be considered at multiple levels, such as social, aesthetic, environmental, economic, functional, and technical.

Social level

Heritage adaptive reuse allows for the social and historical values of heritage buildings to be preserved for the present and future (Langston et al., 2008; Latham, 2000; Shipley et al., 2006a). Heritage adaptive reuse also helps to maintain a sense of place (Bullen & Love, 2011a; Langston et al., 2008) and to provide status to property owners (Ball, 2002; Douet, 2012; Langston et al., 2008). Moreover, heritage adaptive reuse contributes to the regeneration of run-down areas (Ball, 1999, 2002; Bullen & Love, 2010; Douet, 2012), reducing crime and vandalism and increasing the quality of life (Langston et al., 2008), and providing hope to communities shattered by the loss of traditional industries (Douglas, 2006; Latham, 2000). It should however be noted that some industrial heritage buildings may still have a stigma attached to them because they evoke unpleasant memories of the industrial past. This may in turn discourage adaptive reuse (Loures, 2008; Wilkinson et al., 2014).

Aesthetic level

Heritage adaptive reuse allows for the preservation of the historic architectural qualities of heritage buildings (Douglas, 2012) while maintaining attractive streetscapes and interfaces (Bullen & Love, 2010, 2011a; Langston et al., 2008). With industrial heritage buildings, the historic architectural qualities can also help to further promote industrial heritage (Douet, 2012). These qualities would, however, be severely compromised or destroyed if radical changes to the structure and fabric of the building were to be made (Douglas, 2006). And ironically, it is often these same qualities that attracted the developer or investor to the building in the first place (Douet, 2012).

Environmental level

Adaptive reuse extends the service life of a building while reducing material consumption and waste, transport, and carbon emissions (Douet, 2012; Douglas, 2006; Langston et al., 2008). Adaptive reuse also retains the building's embodied energy (Bullen & Love, 2011c; Douet, 2012; Langston et al., 2008) and reduces the use of greenfield locations (Ball, 2002; Douglas, 2006; Langston et al., 2008). Moreover, adaptive reuse allows for equipping candidate buildings with green and energy-efficient materials, improving energy performance and reducing associated greenhouse gas emissions (Bullen & Love, 2010; Douglas, 2006; Langston et al., 2008). However, adaptive reuse can also bring about challenges to greening historic buildings. Implementing sustainable solutions in historic heritage buildings can, according to Bullen and Love (2010, 2011c), prove technically hard and, according to Yung and Chan (2012), also detract from the heritage features of the buildings. Another concern is that many historic industrial buildings are impacted by site contamination, which can present serious risks to public health and the environment (Loures, 2015; Wilkinson et al., 2014).

Economic level

Heritage adaptive reuse can offer several economic benefits to local communities and governments. It can promote heritage tourism (Egbert, 2012) and create job opportunities (Loures, 2015; Stratton, 2000; Wilkinson et al., 2014), deliver affordable housing (Bullen & Love, 2011c; Loures, 2015; Wilkinson et al., 2014) and low-cost workspaces (Ball, 1999, 2002) while attracting new services and facilities (Latham, 2000; Williamson, 2010). Heritage adaptive reuse can also contribute to increased tax revenues associated with higher property values (Cyrenne, Fenton, & Warbanski, 2006; Shipley et al., 2006b). Shortage of traditional materials and skilled heritage workers is, however, one big consideration when adaptively reusing historic heritage buildings, and so is a saturated demand for suitable new uses in the area (Douglas, 2006).

Functional level

Adaptive reuse can create accessible and functional spaces from disused buildings (Ball, 2002; Bullen & Love, 2011a; Wilkinson et al., 2014), providing a more appealing experience than with new build (Douet, 2012; Langston et al., 2008; Latham, 2000). However, while a building may be ripe for adaptive reuse, the new use may not always be consistent with the previous use. Also, the geometry of historic buildings can be unsympathetic to current needs (Bullen & Love, 2010; Douglas, 2006).

Technical level

Adaptive reuse generally requires buildings to be upgraded to comply with current building and safety regulations (Williamson, 2010). In the case of historic buildings, however, these regulations are often hard to meet due to spatial and constructional limitations (Bullen & Love, 2011a; Douglas, 2006; Langston et al., 2008). Nevertheless, a great number of historic buildings are capable of performing surprisingly well against current regulations due to factors inherent in the buildings. Many historic factories and warehouses are of solid and sound construction with thick and permeable walls, offering good thermal mass, moisture regulation, and strength for construction handling (Douet, 2012; Douglas, 2006; Langston et al., 2008). Yet, some historic buildings may be in such poor condition that they require extensive repairs and refurbishment work (Bullen & Love, 2010, 2011a; Douglas, 2006). Moreover, the existing components and materials may be difficult to match as they may no longer be available or hard to come by. Consequently, replacements may have to be custom-made, using new materials that probably have a different performance. Also, the original building techniques may be unknown, if not outdated (Bullen & Love, 2011a; Douglas, 2006). Nevertheless, buildings being adaptively reused can provide a safe and dry workplace because their structure and fabric can be fully utilized to shelter ongoing work and store materials and equipment. Existing building services, such as electrics, plumbing, heating, ventilation, and air conditioning, can as far as possible also be reused, saving time and money (Douglas, 2006).

3.5 Economics

An often-heard claim by developers and investors is that adaptive reuse, and particularly heritage adaptive reuse, is more costly than building anew (Bullen & Love, 2011a; Dyson et al., 2015; Loures, 2015). Demolition and replacement are then said to be the only way to obtain a profitable return from the use of the land. At the same time, a growing number of developers and investors seem to be able to deliver exciting and profitable heritage adaptive reuse projects. So far, there is little evidence to support either side of the debate. According to Mason (2005), this is attributed to the lack of experts and research institutes dealing with the topic of heritage preservation. Shipley et al. (2006a) added that there is an unwillingness of developers and investors to share financial data. A good starting point in assessing the financial viability of adaptive reuse is to compare the costs of adaptive reuse and comparable new build projects (Douglas, 2006; Shipley et al., 2006a). This method works based on adaptive reuse being adopted so long as its cost doesn't surpass the cost of new build but is a very crude and straightforward way of determining project viability. A more realistic approach is to compare the investment results or cash flows of adaptive reuse and comparable new build projects. The option with the highest return on investment or net present value is generally the most viable (Douglas, 2006; Stas, 2007). Both methods are discussed below.

3.5.1 Cost approach

The cost of adaptive reuse is commonly defined as the total cost of adapting and delivering a building and includes the land and building acquisition costs, the hard costs (i.e., construction costs), and the soft costs (i.e., architectural and engineering fees, insurance and permitting costs). The cost of new build is commonly defined as the total cost of constructing and delivering a building and includes the land acquisition costs and the hard and soft costs. If existing structures need to be removed first, the hard costs will also include demolition costs. The construction costs of adaptive reuse are generally lower than those of new build because major cost savings can be made with the floors, walls, and roof already in place. This will in turn result in shorter construction periods and lower borrowing costs (Ball, 2002; Douglas, 2006; Highfield, 2000). Extra cost savings can be achieved if any of the building services (e.g., electrics, plumbing, heating, ventilation, air conditioning) can be reused. Despite these savings, the cost of adaptive reuse, and particularly heritage adaptive reuse, can be significantly affected by market factors and factors inherent in the building itself. Some of these factors are outlined below.

- Market factors such as land and property prices and availability and cost of skilled heritage workers and traditional materials can vary widely from place to place and significantly impact acquisition and construction costs (Shipley et al., 2006a).
- Deferred maintenance of some historic heritage buildings can result in higher construction costs due to extensive repairs and restoration work (Ball, 2002; Douglas, 2006; Wilkinson et al., 2014).
- Compliance of historic buildings with current building and safety regulations may require extensive and corrective work (Bullen & Love, 2011c; Douglas, 2006; Shipley et al., 2006a).
- The geometry of some historic buildings can be unsympathetic to the new use, resulting in unused space that still has to be accounted for in the costs (Shipley, Utz, & Parsons, 2006b).
- The extent and quality finish of the adaptations will largely affect the cost of adaptive reuse because the higher these are, the higher the costs will be (Douglas, 2006; Shipley et al., 2006b).

- The presence of hazardous materials (e.g., asbestos, lead) in the building and the soil beneath it will likely result in higher adaptive reuse costs due to extensive and costly remediation work (Douglas, 2006; Langston et al., 2008; Latham, 2000).
- Latent conditions and other unexpected events throughout the construction period can further increase the cost of adaptive reuse (Douglas, 2006; Shipley et al., 2006a).

So far, few studies have addressed adaptive reuse in terms of cost. Shipley et al. (2006b) compared the cost of heritage adaptive reuse with the cost of new build in Canada. They considered the total cost of bringing the buildings to market and adjusted for government incentives such as grants, tax credits, and waived fees. They found that adaptive reuse wasn't always cheaper than new build. Especially for large residential conversions, the cost per square foot was much higher (44%) than when building anew. For large commercial conversions, however, the cost per square foot was much lower (38%) than when building anew. Stas (2007) compared the cost of adaptively reusing historic buildings into affordable housing in Canada with the cost of comparable new buildings. The results showed that the cost of adaptive reuse per square foot was lower (9 to 13%) than the cost per square foot of new build. When grants and tax credits were applied, the cost difference was even greater. Similarly, Schalmo (2008) compared the cost of affordable residential conversions of historic buildings in the United States with the cost of comparable new buildings. He found that the cost of adaptive reuse per square foot was almost equal to the cost of new build. The results of these studies suggest that although the cost difference between adaptive reuse and new build varied greatly between and among the studies, heritage adaptive reuse can be very competitive, if not cheaper than new build. It should, however, be noted that these findings were derived from limited case studies and must, therefore, be tempered by this limitation.

3.5.2 ROI / NPV approach

While a comparison between the costs of adaptive reuse and new build will determine the lowest cost option, it doesn't provide insight into which option offers the best return or value to investors. The return on investment (ROI) measures the amount of profitability on the amount invested and is given by the ratio of the net operating income and the capital cost. The net operating income is the difference between the income generated by the property (i.e., rentals minus vacancy) and the operating expenses (property taxes, repair and maintenance, and insurance). If leverage is applied, then the net operating income is also deducted by the debt services. The capital cost is the total amount invested, which is the cost of adaptive reuse or new build minus any grants received (Peca, 2009). It should be noted that historic buildings generally have lower rents than new buildings because they usually can't fully meet current user needs (Douglas, 2006; Ellison & Sayce, 2007). And even when they have been adaptively reused, their operating expenses are often still higher than those of new buildings because the building's age and condition of the structure and services directly impact the maintenance costs (Bullen & Love, 2011b, 2011c; Douglas, 2006).

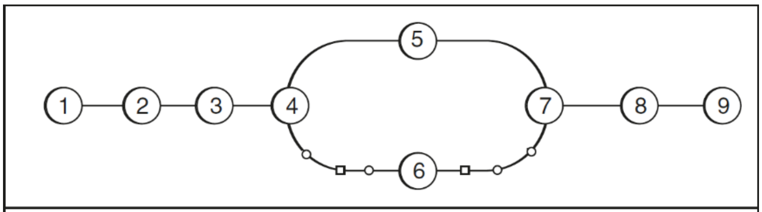
The net present value (NPV) measures the total amount of gain or loss an investment will produce and is given by the difference between the present value of cash inflows (rentals) and the present value of cash outflows (capital cost, operating expenses, and debt services) over a period of time.

So far, very few studies have addressed adaptive reuse in terms of value or return on investment. Stas (2007) compared the ROI of adaptively reusing historic buildings into affordable housing in Canada with the ROI of comparable new buildings. The results showed that the ROI of adaptive reuse was higher (12 to 19%) than that of new build. When leverage and government incentives were applied, the ROI differences were even greater. Shipley et al. (2006b) gathered comments from heritage developers on the anticipated ROI for their adaptive reuse projects. Despite the varying responses, the overall impression was that the business of heritage adaptive reuse can be very profitable, even if not always right away.

Fundamentally, all commercial development propositions need to demonstrate the ability to make money, otherwise, they will be omitted. Based on the discussions above, it can be argued that heritage adaptive reuse can be as profitable as (or even more profitable than) new build, though there is no magic formula. Each adaptive reuse project is unique and assessing financial viability can be a complex exercise, given the variety of factors inherent in the building and location and factors inherent in the process itself. Therefore, proper assessments should be carried out throughout the project to ensure value and return on investment.

3.6 Process and stakeholders

Adaptive reuse is a process in the life cycle of a building. Figure 3.3 (Douglas, 2006, p. 20) illustrates a linear model of the whole life cycle of a building. In the first three stages, decision, design, and construction, the building is planned, designed, and constructed according to the owner's and occupants' needs. In the following stage, the occupancy stage, the building begins use for its intended purpose and starts to depreciate. Subsequently, the building enters the maintenance stage, which alternates with the adaptation stage. Some types of buildings, such as churches and schools, may retain their original use for decades through maintenance and adaptation. For other types of buildings, such as shops and offices, the original use may not be viable for more than a few



Notes
1. Decision to build.
2. Design stage.
3. Construction stage.
4. Occupancy.
5. Maintenance.
6. Adaptation (circles represent regular improvements; the square represents occasional, major changes).
7. Irreversible building obsolescence sets in.
8. Building fully obsolete.
9. Dispose/demolish.

Figure 3.3. A linear model of the whole life cycle of a building. Reprinted from *Building adaptation* (2nd ed., p. 20), by J. Douglas, 2006, Oxford, England: Elsevier. Copyright 2006 by James Douglas.

decades due to obsolescence and redundancy. Through adaptive reuse, the building can then be converted to other more efficient and effective uses such that it can better serve user needs and have a useful extended life. At a certain point in the life cycle of the building, irreversible obsolescence sets in. When the building becomes fully obsolete to the owner and occupants, it is disposed of or demolished. Douglas (2006) divided the adaptive reuse process into four stages: incubation, negotiation, construction, and management. These stages are discussed below.

Stage 1: Incubation

In the incubation stage, potential uses for the building are explored and a plan is devised. In the case of heritage buildings, new uses should respect the historical character of the building and involve minimal changes to its fabric, interior, and setting. Local authority and public support should be sought early on while preliminary appraisal must establish project viability and desirability.

Stage 2: Negotiation

In the negotiation stage, finance is raised and negotiations for the building purchase are carried out. Also, detailed designs are made and planning permission is obtained. A competent production team (architects, builders, engineers, surveyors, and heritage experts) with the skills and knowledge to handle the challenges posed by heritage buildings (see Sections 3.4 and 3.5) should be selected.

Stage 3: Construction

In the construction stage, adaptation work is carried out on the building. Efficient project management is essential to keep costs and quality under control and finish the project on time.

Stage 4: Management

In the management stage, the completed plan is communicated to all stakeholders involved, and an adequate management strategy for the converted building is adopted and implemented.

In each of these stages, different stakeholders with different interests are involved. Douglas (2006) and Kincaid (2002) distinguished six stakeholder groups in adaptive reuse projects: investors, producers, marketers, regulators, users, and developers. These groups are listed in Table 3.1 (Douglas, 2006, p. 83) including a description of their involvement. With heritage buildings, there are additional parties involved such as heritage experts (producers), heritage officials (regulators), and heritage advocates and enthusiasts. For the latter, the study proposed a seventh stakeholder group: conservationists. Conservationists do play an important role in heritage conservation.

Table 3.1
Adaptive reuse stakeholders

Stakeholder groups	Involvement	Stage	Examples
Investors	Arrange capital to fund adaptive reuse projects and purchase buildings	1-4	Banks, finance companies, insurance companies, and pension funds.

Producers	Design, specify, cost, and execute adaptation projects	1-3	Architects, builders, engineers, surveyors, and heritage experts.
Marketeers	Find users for buildings and buildings for users	3-4	Estate agents and surveyors.
Regulators	Ensure compliance with the statutory requirements	1-3	Building Control, Fire Authority, Health and Safety Executive, and heritage officials.
Users	Occupy, manage, and use the building	4	Individual users, facility, and maintenance managers.
Developers	Undertake some or all of the investor, producer, and marketing roles above	1-3	Contractors and development companies.
Conservationists	Advocate or act for the protection and preservation of heritage buildings	1-4	Heritage advocates and enthusiasts.

Note. Adapted from *Building adaptation* (p. 83), by J. Douglas, 2006, Oxford, England: Elsevier. Copyright 2006 by James Douglas.

3.7 Building factors

Some industrial heritage buildings have more potential for adaptive reuse than others. As discussed in Chapter 1, the building itself is considered one of the two most important aspects of adaptive reuse. Through literature review, building attributes considered important factors of (industrial heritage) adaptive reuse were identified and are presented below. Some may have a stronger effect on adaptive reuse than others and some may even affect one another.

Building type

Single-purpose industrial buildings, such as mining buildings and metal-working and power plants, are considered more difficult to adaptively reuse than universal industrial buildings that are amenable to multiple uses. This is mainly because these building types usually have the technology built directly into their structure, shaping their layout and appearance. These building types are also often very large and extremely contaminated (Bullen & Love, 2010; Douet, 2012; Douglas, 2006).

Building age

Buildings approaching their effective physical life will, according to Langston et al. (2008), have lesser adaptive reuse potential. According to Bullen and Love (2011c), it is the residual service life of a building that helps determine its adaptive reuse potential because buildings with a short residual service life many times bring about structural and fabric problems requiring extensive and costly adaptations. In this regard, a British study showed that industrial buildings from the post-war era were more often reused than those from the pre-war era (Ball, 1999, 2002).

Building structure

The building structure is considered important for adaptive reuse (Douglas, 2006; Gann & Barlow, 1996; Kincaid, 2002). A Canadian study found that particularly industrial buildings with wooden structures were troublesome to extend because the structure couldn't withstand the additional forces caused by construction loads (Wilson, 2010). Furthermore, two British studies found that steel frame buildings were more preferred by industry professionals for adaptive reuse than brick-walled or concrete frame buildings (Gann and Barlow, 1996; Kincaid, 2002). This had mainly to do with steel being easier to work with and cut through. Yet, many historic brick or stone buildings do provide good thermal mass, moisture regulation, and strength for construction handling exactly because of their thick solid walls (Douet, 2012; Douglas, 2006; Langston et al., 2008).

Building condition

The building condition is considered important for adaptive reuse (Douglas, 2006; Oevermann & Mieg, 2014; Stratton, 2000). This is because a deteriorated structure and fabric will require more costly maintenance and repair and thus adversely affect construction costs (Bullen & Love, 2010, 2011b; Wilkinson et al., 2014). A British study found that industrial buildings in good condition were more often reused than those in poor condition (Ball, 1999, 2002).

Building contamination

The presence of contaminants in the building will directly impact the ease and cost of adaptive reuse (Douglas, 2006; Langston et al., 2008; Latham, 2000). For instance, the use of asbestos in building materials can cause trouble as asbestos is difficult to remove without harming the structural integrity of the building (Wilkinson et al., 2014).

Building shape

The building shape is considered important for adaptive reuse (Bullen & Love, 2010; Douglas, 2006; Dyson et al., 2015). Square or rectangular buildings are, according to Douglas (2006), easier and cheaper to adapt or reconfigure spatially than circular or irregular-shaped buildings.

Building size

Small buildings possess, according to Ball (2002), more market appeal than large buildings, but the latter can be more attractive to developers for subdivision. A British study found that large buildings were more preferred by industry professionals for residential conversions than small buildings (Gann and Barlow, 1996). This had to do with large buildings allowing for a higher number of units and therefore higher yields than small buildings. With large buildings, however, there can be serious consequences for parking and building operations due to higher occupant densities. Both Alfrey and Putnam (1992) and Oevermann and Mieg (2014) claimed that large industrial buildings are difficult to convert to suitable new uses. While there is no optimal building size for adaptive reuse, Stratton (2000) proposed that a total floor area of 4.500 to 15.000 square meters is satisfying for many adaptive reuse plans, while a floor area below 1000 or above 15.000 square meters is challenging. A British study found that industrial buildings of less than 5000 square feet were more often reused than those of 5000 square meters or more (Ball, 2002).

Building height

Low buildings are, according to Bullen and Love (2010, 2011c), less suitable for adaptive reuse than tall buildings. Douglas (2006) noted that the building height can largely affect the interior and exterior adaptation. Gann and Barlow (1996) claimed that the building height is an aspect of consideration but “unlikely to be a major constraint on conversion because the overall floor area is likely to impose limitations due to high densities which override the issue of height” (p. 59).

Building length

Buildings of 15 meters long or less are, according to Stratton (2000), ideal for uses requiring good natural light, whereas buildings longer than 15 meters will need artificial lighting. According to Gann and Barlow (1996), it is ultimately the distance from the core to the windows that is decisive. This is because the greater this distance is, the more problems with natural light and ventilation there will be in areas close to the core, especially in the case of residential uses.

Ceiling height

The ceiling height is considered important for adaptive reuse because it determines what services can be fitted within raised floors or ceiling voids (Douglas, 2006; Kincaid, 2002; Latham, 2000). Although the optimal ceiling height varies with use, Latham (2000) argued that buildings with low ceilings are difficult to adapt to new uses. Stratton (2000) even suggested that buildings with ceiling heights lower than 2,4 meters are less suitable for new types of uses.

Window area

The window area is considered important for adaptive reuse because buildings with large window areas tend to be easier to let or sell than those with smaller window areas (Gann & Barlow, 1996; Kincaid, 2002; Stratton, 2000). Large window areas may, however, cause solar heat gain or heat loss due to the insulation properties of the glass (Kincaid, 2002; Stratton, 2000).

Building accessibility

Building accessibility refers to the ease or difficulty of entering a building and is considered important for adaptive reuse, especially when concerning disabled and less-mobile people (Bullen & Love, 2011a; Gann & Barlow, 1996; Kincaid, 2002). Wilkinson et al. (2014) claimed that the more access points a building has, the more suitable it is for adaptive reuse.

Building layout

The building layout is considered important for adaptive reuse (Douglas, 2006; Gann and Barlow, 1996; Kincaid, 2002). Both Bullen and Love (2011b) and Stratton (2000) argued that buildings with open interior spaces and columns widely spaced allow greater flexibility for adaptive reuse. Ellison and Sayce (2007) claimed that a restrictive layout or configuration will result in the depreciation of the building, which could affect the viability of adaptive reuse.

Building aesthetics

Building aesthetics are one of the main aspects considered in architecture. They describe the overall appearance of a building, both inside and out. Bullen and Love (2010, 2011b) argued that buildings of aesthetic quality are financially attractive for adaptive reuse. Kincaid (2002) and Shipley et al. (2006a), too, claimed that the aesthetic quality of a building is key to its market value. In this regard, a British study revealed that the design and heritage features of industrial buildings were paramount to their reuse potential (Ball, 1999, 2002).

Listed monument status

Buildings listed as monuments possess high historical and architectural values, which are considered key to their marketability and market value (Ball, 1999, 2002; Bullen & Love, 2010, 2011b). A Dutch and a U.S. study showed that buildings with listed status were priced higher than those without (Lazrak, Nijkamp, Rietveld, & Rouwendal, 2014; Sandy & Tu, 2008). Listed buildings also enjoy protection against unauthorized demolition or alteration and generally have service lives extending beyond their physical lives. However, listed buildings can be severely limited in the uses and changes allowed. Unlisted buildings, on the other hand, can be adapted to serve various types of uses (Douglas, 2006; Latham, 2000).

3.8 Locational aspects

Depending on their location, some industrial heritage buildings may be more conducive to adaptive reuse than others. As discussed in Chapter 1, the building's location is regarded as one of the two most important aspects of adaptive reuse. To get an understanding of the forces that drive real estate location decisions, this section first briefly discusses previous efforts in location theory. In light of these efforts, this section then addresses a set of location attributes considered in the literature as important factors of industrial heritage adaptive reuse.

3.8.1 Location theory

When assessing a building's location for adaptive reuse, it is important to consider the forces that drive real estate location decisions. In the last two centuries, there have been many efforts to provide a theoretical underpinning of location. Various geometric and arithmetic models have been developed to analyze the location patterns of urban land uses, particularly those of productive and commercial land uses. One of the generally observed phenomena is that most urban activities tend to be clustered in space, be it in the form of cities, towns, or villages. Different activities will show different spatial clustering patterns, depending on the extent to which they benefit from spatial proximity. Economies of scale, economies of scope, and economies of synergy, all are benefits that can be reaped from spatial clustering. And at the same time, there is also a tendency for some activities to be spatially dispersed, which is often driven by the need for space and the need to bring services closer to customers (McCann, 2001, Schiller, 2001). In Chapter 2, it was already explained how in the industrial age, each industry in the Netherlands was clustered in a specific region of the country to be close to labor, raw materials, and markets. On a local urban scale, rapidly growing industries successively dispersed from the core to peripheral areas. This touches on another phenomenon in location theory in which the patterns of spatial clustering and dispersal bring about a hierarchical pattern of urban clusters within a country or region. In this hierarchical pattern, the largest cluster (i.e., the dominant city) exhibits almost all urban activities, and the following smaller clusters, which grow in number as their size diminishes, display a smaller range of activities. This is graphically shown in Figure 3.4 (McCann, 2001, p. 72). The particular theory that deals with this phenomenon is known as the *Central Place Theory* and was pioneered by William Christaller (McCann, 2001; Schiller, 2001). When applied to industrial heritage buildings in the Netherlands, the theory would propose that only those buildings located in higher-order clusters (major towns and cities) would normally have access to the resources required to support adaptive reuse practices. In contrast, buildings located in lower-order clusters (smaller towns and villages) would have less access to these resources and would thus be less likely to undergo adaptive reuse. While there could be several reasons for this empirical regularity, decreasing densities and market opportunities are likely the most important (Latham, 2000; Salvaneschi 2003).

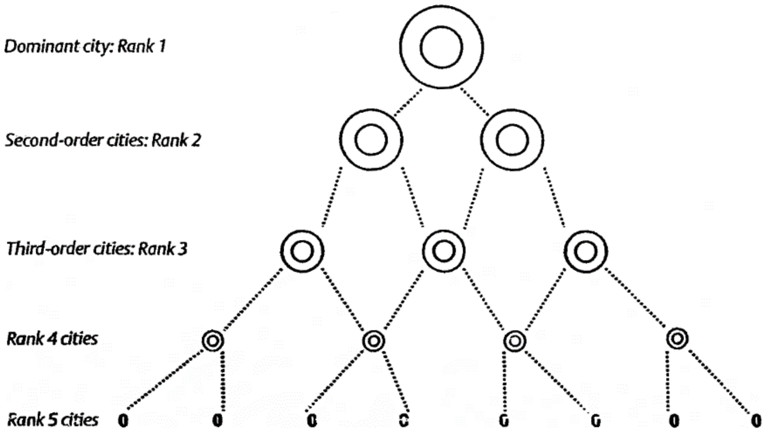


Figure 3.4. The spatial and hierarchical organization of the urban system. Reprinted from *Urban and regional economics* (p. 72), by P. McCann, 2001, Oxford, England: Oxford University Press. Copyright 2001 by Philip McCann.

On a local urban scale, it is the relative location of a building within the city that could further determine its potential for adaptive reuse. From classical rent theories (by Ricardo, Von Thünen, William Alonso, and others), it follows that in a monocentric city, rents are the highest in the city center as a result of different land uses competing with each other for land there (highest and best use concept). This is assuming that most business and commercial activities are concentrated in the city center. The rents then tend to fall with increasing distance from the center at a diminishing rate to compensate for the increase in transport costs to the center (McCann, 2001, Schiller, 2001). This is graphically shown in Figure 3.5 (McCann, 2001, p. 101). In reality, large cities can be far from monocentric and may have one or more sub-centers that function as local hubs for business and commercial activities. These sub-centers will likely cause smaller peaks in the bid-rent curve, as shown in Figure 3.6 (McCann, 2001, p. 120). However, land not only differs according to relative location (non-homogeneous) but is also associated with different environmental amenities and disamenities at a particular location. These amenities and disamenities will presumably be reflected in the rents at that particular location. The environmental amenities may include water bodies, green spaces, and scenic views, while the disamenities may be associated with air and noise pollution and crime (DiPasquale & Weathon,1996; McCann, 2001). Changes in these amenities and disamenities will likely cause a further increase, fall, or even change of sign in the bid-rent curve as the distance from the city center grows. According to McCann (2001), at the larger metropolitan scale, it still holds that the greater the distance from the core is, the lower the rents tend to be. The highest rents and lowest yields are found in the most desirable locations, and it is in these areas of high value that development, from an investment perspective, should mostly take place (Li & Brown, 1980; Schiller, 2001). This lines up with the notion of functional completeness, wherein a location that offers all sorts of amenities and facilities is key to commercial success (Salvaneschi 2003). Therefore, it can be argued that industrial heritage buildings located in or near the commercial centers of major towns and cities can be good investment opportunities.

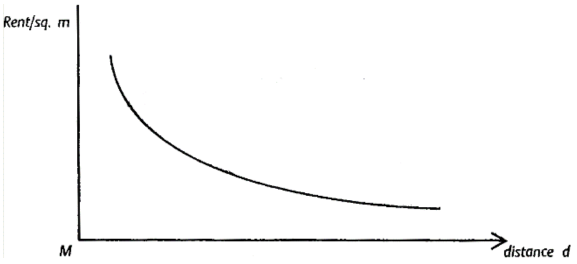


Figure 3.5. Bid-rent curve for a monocentric city. Adapted from *Urban and regional economics* (p. 101), by P. McCann, 2001, Oxford, England: Oxford University Press. Copyright 2001 by Philip McCann.

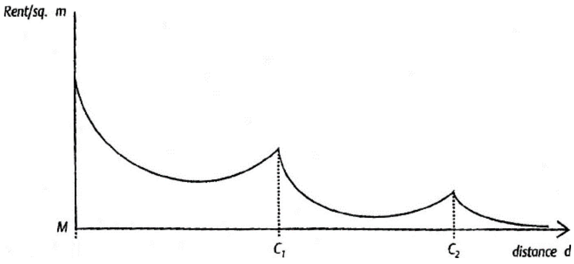


Figure 3.6. Bid-rent curve for a multicentric city. Adapted from *Urban and regional economics* (p. 120), by P. McCann, 2001, Oxford, England: Oxford University Press. Copyright 2001 by Philip McCann.

3.8.2 Location factors

The geographic location of a building can be described in terms of *site* and *situation*. Site refers to the lot on which the building is located and is defined by the physical attributes of the lot. These attributes can affect the development costs on the lot. Situation refers to the location of the building relative to its surroundings and how these affect the project. The situation is largely determined by the demographic and socioeconomic attributes of the surrounding area and is further defined by descriptive measurements such as distance to amenities and transport links. As discussed in the previous subsection, these attributes contribute or detract from the attractiveness of a location and will presumably be reflected in the property prices at that particular location (Buckner,1998; Thrall, 2002). In light of these considerations, location attributes considered in the literature as important factors of (industrial heritage) adaptive reuse were identified and are presented below. Some may have a stronger effect on adaptive than others and some may even affect one another.

Site coverage

The site coverage denotes the percentage of the site that is covered by the building. According to Stratton (2000), densely built sites are more likely to be surrounded by activity but may be affected by congestion. Sparsely built sites, on the other hand, may allow for building expansion, car parking, easier access, and increased natural light but may be distant and unsafe. Both Stratton and Douglas (2006) claimed that a built-up area of more than 60 percent is a deterrent to adaptive reuse.

On-site parking

On-site parking refers to the parking available on the site and is considered important for adaptive reuse (Kincaid, 2002; Stratton, 2000). On-site parking adds to the attractiveness of the building and helps increase its market value (Dunse and Jones,1998).

Site contamination

Site contamination is the presence of substances on or below the site surface that are harmful to human health or the environment. Site contamination will likely affect the ease and cost of adaptive reuse due to extensive and costly remediation (Douglas, 2006; Langston et al., 2008; Latham, 2000).

Site zoning

Zoning is the classification of land according to limitations set on its use and development. Zoning may discourage adaptive reuse because zoning regulations may restrict or prohibit a new use (Tan, Shen, & Langston, 2014; Tan, Shuai, & Wang, T., 2018; Yap, 2013). One of the reasons for this is that air and noise pollution levels of surrounding (industrial) activities may exceed those set for the intended use. Although a change of zoning can be appealed, Yap (2013) claimed that a change from industrial zoning to appropriate zoning required for the intended use is difficult because it can take a long time and, therefore, increase project cost and risk.

Location type

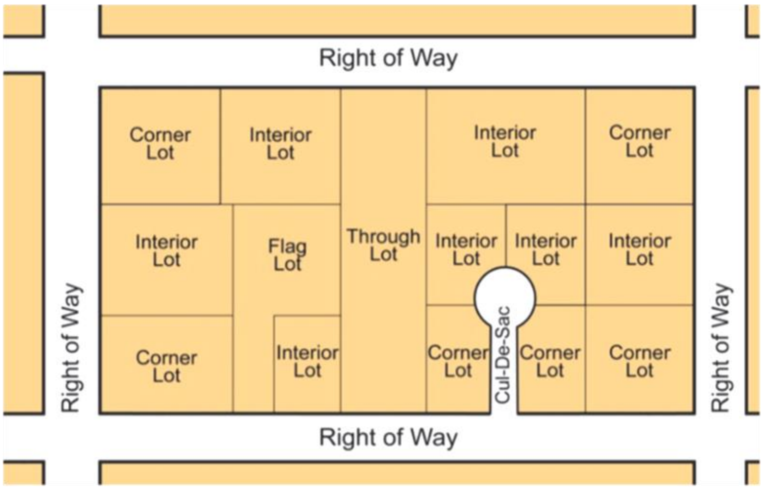
The location type is considered important for adaptive reuse (Latham, 2000; Stratton, 2000; Warner et al., 1980). A general classification of location based on the population density is the one into urban, suburban, and rural. Salvaneschi (2002) argued that population density is important for commercial development regardless of the right demographics and lifestyles that may suit a business. This would be because distances to services and facilities in areas of high population density are shorter than those in areas of low population density, resulting in less inconvenience to customers. This would presumably be reflected in higher sales volumes and profits and, therefore, in higher rents. Latham (2000), too, noted that market conditions can vary depending on the location type such that an adaptive reuse project that turns out profitable in the city may not be lucrative in the countryside. Based on the above, it could be argued that the more urban the location, the more likely the commercial success of adaptive reuse. In the Netherlands, Statistics Netherlands (http://www.cbs.nl) uses a 5-grade classification of location that is based on the surrounding address density (SAD). The SAD is the average number of addresses within a one-kilometer radius. The grades are as follows: extremely urbanized (SAD of 2500 or more), strongly urbanized (SAD of 1500 to 2500), moderately urbanized (SAD of 1000 to 1500), hardly urbanized (SAD of 500 to 1000), and not urbanized areas (SAD lower than 500). The SAD aims to reflect the degree of concentration of human activities, such as living, learning, working, shopping, and playing.

Location in a conservation area

Conservation areas are areas that have been designated as being of special architectural or historical interest. Buildings in such areas enjoy protection against unauthorized demolition and alteration but can be limited in the changes allowed (Douglas, 2006). Buildings in conservation areas may also have higher market values than those outside such areas, which is likely attributed to the value spillover effects of the clustering of built cultural heritage (Lazrak et al., 2014; Ilja, 2008). Based on the above, it could be argued that location in a conservation area contributes to adaptive reuse success. A U.S. study showed that historic textile mills in historic districts were more likely to undergo adaptive reuse than those outside such areas (Briggs, 2010).

Location visibility

Location visibility refers to the ease with which a building can be seen from as many directions and from as far away as possible. It can be considered in terms of the building lot position relative to the adjoining lots and roads, as shown in Figure 3.7 (The City of Lakewood, 2021). Corner lots do offer high visibility (Salvaneschi, 2002), while through and interior lots arguably provide lesser visibility and flag lots the least. Location visibility can also be seen in terms of the building's position relative to the road. Buildings closer to the fronting road certainly have higher visibility than those further away. Location visibility affects the ability of (first-time) users and customers to find a particular building and the top-of-mind awareness of the building, which, in the case of commercial uses, will presumably be reflected in higher sales volumes and profits and, hence, in higher rents (Buckner, 1998; Salvaneschi, 2002). In this regard, Schiller (2001) and Rabianski, Gibler, Clements, and Tidwell (2009) stressed the importance of location visibility in real estate developments.



building

Figure 3.7. Types of lot. Reprinted from *Subdivision Ordinance of the City of Lakewood, Colorado* (p. 9), by the City of Lakewood, Colorado, retrieved from https://www.lakewood.org/Government/Departments/Planning/Subdivision-Ordinance/ Copyright 2021 by the City of Lakewood, Colorado.

Location exposure

Location exposure refers to the exposure a building receives from passing traffic. Generally, the higher the class of the fronting road, the more exposure the building receives. This is because higher-class roads carry higher volumes of traffic than lower-class roads (Salvaneschi 2002; Schiller, 2001). Especially with commercial uses, it is important to attract as many customers as possible to achieve the highest sales volumes and profits. Having good location exposure will likely contribute to these goals. Exposure to major roads may, however, also lead to disamenities such as air and noise pollution and traffic congestion, which may cause property values to fall (Li & Brown, 1980; Visser et al., 2008; Wilkinson et al., 2014). The Netherlands has several road classifications, which are published on the website of the Department of Waterways and Public Works (http://www.infomil.nl). One of these classifications is the Sustainable Safety Road classification[2], which consists of three main road categories: through roads, distributor roads, and access roads. Through roads are high-capacity roads (over 15,000 motor vehicles per day) that serve to move traffic from origin to destination as quickly and safely as possible. They usually have no intersections and the minimum speed limit is 100 km/h. Distributor roads are moderate-capacity roads (4,000 – 15,000 motor vehicles per day) that connect through roads with access roads. The speed limit varies from 50 or 70 km/h in urban areas to 80 km/h in rural areas. Access roads are low-capacity roads (under 4,000 motor vehicles per day) that provide access to homes and businesses. The speed limit varies from 15 or 30 km/h in urban areas to 60 km/h in rural areas.

Transport accessibility

Transport accessibility refers to the ease with which users and customers can get to a building. It is usually measured in terms of distance from transport links, such as highways, train stations, and bus and tram stops (Schiller, 2001; Stratton, 2000). Buildings with good transport accessibility tend to be higher in demand than those without and, therefore, tend to have higher market values (Ellison & Sayce, 2007; Netzell, 2013). In this regard, Stratton (2000) claimed that buildings in good accessible locations are more conducive to adaptive reuse than those in poorly accessible locations. A British study showed that industrial buildings within 8 kilometers of a motorway junction were more often reused than those further away (Ball, 2000). Proximity to transport links may, however, also lead to disamenities such as air and noise pollution and traffic congestion, which may cause property values to fall (Li & Brown, 1980; Visser et al., 2008; Wilkinson et al., 2014).

Access to amenities

Access to amenities refers to the ability to reach desired services and facilities within a given area and their proximity to one another. It can be considered in terms of distance to city centers, green spaces, water bodies, etc. The previous subsection already discussed how increasing proximity to amenities will likely cause property values to rise (DiPasquale & Weathon,1996; McCann, 2001). In this regard, Kincaid (2002) and Stratton (2000) suggested that being close to amenities can significantly encourage adaptive reuse. Although it is not possible to establish a general rule regarding the intensity of the proximity effect (due to variation in type, size, and spatial distribution of amenities), several studies have offered tentative answers regarding the distance over which the proximity effect extends. In the case of green spaces, two U.S. studies showed that most of the value increases in house prices occurred within 450 m of a park (Lutzenhiser & Netusil, 2001; Espey & Owusu-Edusei, 2001) or even within 150 m (Crompton, 2005). As for water bodies, a Dutch study and a British study found that the proximity effect on house prices drastically diminished beyond 50 m (Rouwendal, Levkovich, & Van Marwijk, 2017; Orford, 2002).

---

[2] The Sustainable Safety Road classification stems from the 1977 Start Program Sustainable Safety covenant between the municipalities, provinces, and national government regarding the road safety in the Netherlands.

Neighborhood demographics

Neighborhood demographics are the data describing the socioeconomic and demographic attributes of a neighborhood, such as average income and education, and employment level. These attributes are typically evaluated differently for various uses. In the case of residential uses, they can be seen as indicators of neighborhood quality that affect the behavior of home buyers and therefore the house prices (Li & Brown, 1980; Visser et al., 2008). In the case of retail uses, neighborhood demographics are often considered in terms of the retail market area. As such, they are used to estimate underlying factors of consumer demand. Consumer demand, in turn, will largely determine the demand for retail property and, therefore, the retail property rents (Jackson, 2001; Thrall, 2002). And in the case of office uses, the neighborhood demographics can be seen as employees' amenities that will presumably be reflected in the office rents (Sivitanidou, 1995). Based on the above, it can be argued that the better the socioeconomic condition of a neighborhood, the higher the property values, and the higher the likelihood of adaptive reuse. However, some argued that other factors such as population density and market demand might still override the effect of neighborhood demographics (Salvaneschi, 2002; Wilson, 2010).

3.9 Summary

Adaptive reuse is the process of converting buildings into other, more efficient, and effective uses such that they can better serve user needs and have an extended useful life. It almost always involves physical changes to the building to facilitate the new use. Adaptive reuse is anything but new but is in response to ongoing social, economic, and environmental changes more and more seen as an effective heritage preservation tool. Adaptive reuse, and particularly heritage adaptive reuse, is not straightforward and may present challenges beyond those faced in new construction. And while adaptive reuse may not always be immediately profitable to developers and investors, it can surely deliver multiple social, economic, and environmental benefits to communities and governments, justifying its usefulness and relevance. In the literature, various building and location attributes of heritage buildings have been proposed as important factors of adaptive reuse. The building attributes will likely affect the ease and cost of adaptive reuse, while the location attributes will probably make the building more or less attractive for adaptive reuse. Yet, there is little consensus as to which of these potential factors are the most important.

4 Research Methodology

This chapter presents the methodology used to empirically determine building and location factors affecting industrial heritage adaptive reuse. The chapter discusses the research design, including the variables of interest, the sampling procedures, and the data collection and analysis techniques. The chapter concludes with a description of the threats to the study's validity.

4.1 Research design

The main objective of the study was to empirically determine building and location factors affecting industrial heritage adaptive reuse in the Netherlands, and specifically to assess the magnitude and significance of the effects of these factors. A binary dependent variable was used to indicate whether a historic industrial building was adaptively reused or not. Based thereon, a case-control design was employed. Case-control studies seek to determine whether one or more independent variables have a causal effect on a binary dependent (outcome) variable. They do so by comparing two existing groups that differ in the outcome. The first group includes cases that have the outcome of interest, while the second group contains controls that do not have it (Porta, Greenland, Hernán, dos Santos Silva, & Last, 2014; Shadish et al., 2002). In contrast, correlational studies seek to determine whether one or more independent variables affect a continuous dependent variable by using only one group of subjects (Fraenkel, Wallen, & Hyun, 2012). Case-control studies are retrospective because they look backward in time from the outcome to the postulated causal factors. Therefore, case-control studies cannot assert that a true causal effect exists between an independent variable and the dependent variable, as opposed to experimental studies. Experimental studies seek to determine whether an independent variable (or treatment) that is deliberately introduced or manipulated causes a change in the dependent variable. They do so by comparing the effects in the treatment group to one or more control groups. Although experimental studies provide the strongest evidence for causation, they are not always ethical or practical (Shadish et al., 2002). In the study at hand, due to the fixed nature of buildings, it was impossible to conduct an adaptive reuse experiment that would allow for the manipulation of independent building and location variables. Also, because the dependent variable was binary, it wasn't possible to adopt a correlational design. For these reasons, the case-control design proved most appropriate.

4.2 Variable operationalization

The literature review revealed various building and location attributes considered important factors of industrial heritage adaptive reuse. While some of these attributes needed to be operationalized into variables that could be empirically tested, others came prepackaged as usable variables and required no further processing. Some attributes had to be omitted from the study due to multiple interpretations or lack of data on them. As mentioned above, the dependent variable REUSED was binary and was defined as whether or not a historic industrial building was adaptively reused. Not being adaptively reused was defined as being vacant. The following subsections discuss the operationalization of the independent building and location variables.

4.2.1 Independent building variables

Fifteen building attributes were identified as potential factors of industrial heritage adaptive reuse. Six of these were excluded from further study. Building condition, building contamination, ceiling height, building accessibility, and building layout were omitted due to a lack of data. Building aesthetics was also left out because its assessment would have been subjective and open to many interpretations. Although conceptions of what should or shouldn't be considered quality in aesthetics exist, they fell outside the scope of the study. The nine remaining building attributes were processed as follows and as shown in Table 4.1. Building type was represented by a six-category variable (BLD) indicating the type of historic industrial building. Building age (AGE) was numerically measured in years. Building structure was assessed as a five-category variable STR indicating the structure type. Building shape was represented by a four-category variable SHP indicating the shape of the building. Building size (SIZE), building height (HEIGHT), and building length (LENGTH) were numerically measured in square meters of floor area, numbers of floors, and meters, respectively. Window area was assessed as a four-category variable WDOA indicating the amount of window area in the building. Listed monument status was represented by a binary variable LSTMON indicating whether the building was listed as a monument. It should be noted that although the attributes building condition and building aesthetics were omitted, they were proxied in part by building age and listed monument status, respectively. This is because the age of a building can, for a great part, explain variations in the building's condition (Wong, Cheung, Yau, Chau, & Ho, 2005; Yau, 2008), and aesthetics is one of the criteria for listing buildings.

4.2.2 Independent location variables

Eleven location attributes and attribute groups were identified as potential factors of industrial heritage adaptive reuse. On-site parking was excluded from further study because it was proxied by site coverage. After all, the higher the site coverage, the less space for parking. Site contamination was also omitted due to a lack of data. The remaining location attributes and attribute groups were processed as follows and as shown in Table 4.1. Site coverage (SITECVR) was measured as a ratio of building footprint to lot size. Site zoning was assessed as a binary variable INDZN indicating whether the site had industrial zoning. Location type was represented by a continuous variable SAD indicating the surrounding address density in 1000 addresses per square kilometer. The higher the surrounding address density, the more urbanized the location. Location in a conservation area was assessed as a binary variable CONSA indicating whether the building was in a conservation area. Location visibility was represented by a five-category variable LOT indicating the type of building lot and by a continuous variable DISRD indicating the distance to the nearest fronting road. Location exposure was assessed by a four-category variable RD indicating the class of the nearest fronting road. The higher the class of the fronting road, the higher the traffic flow and thus the location exposure. Transport accessibility was represented by three continuous variables DISBUS, DISSTA, and DISHWY indicating the distances to the nearest bus or tram stop, train station, and highway ramp, respectively. Access to amenities was assessed by a continuous variable DISCITY indicating the distance to the nearest city center and by two binary variables WTR50 and GRN150 indicating whether the building was within 50 m of a public waterbody and within 150 m of public green space (>1 ha), respectively. As for DISCITY, a city was defined as an urban center with a population of at least 50,000 and a minimum density of 1,500 inhabitants per square kilometer (Dijkstra & Poelman, 2012). Neighborhood demographics were represented by a continuous variable STAT indicating the area status score. The area status score indicates the socioeconomic status of a 4-digit postal code area in the Netherlands and used to be published yearly by the Netherlands Institute for Social Research (SCP, 2017). It is derived through factor analysis from population attributes such as average income, percentage of people with low income and low education level, and percentage of unemployed people in the labor force. The higher the status score, the higher the socioeconomic status of the area. The study gave preference to the area status score rather than individual demographic and socioeconomic attributes mainly because the latter usually strongly correlate with each other (Visser et al., 2008). Also, the lack of population data at the neighborhood level would have hindered data collection. To control for possible regional differences in adaptive reuse, an eleven-category variable PR was included indicating the province location of the building. Because no buildings were sampled in the province of Flevoland, PR had 11 categories instead of 12. In total, there were 15 independent location variables.

Table 4.1

Operationalization of independent variables

Attribute/ Attribute group	Variable	Description	Measurement scale and coding	Data source (see Section 4.4)
Building type	BLD	Building type	Nominal: BLD_FAC = factory BLD_NRG = energy supply BLD_WH = warehouse BLD_WS = workshop BLD_WTR = water supply BLD_OTH = other	http://herbestemming.nu, http://boei.nl, http://nrpguldenfeniks.nl, http://sien-n.nl, http://cultureelerfgoed.nl, http://google.com/maps
Building age	AGE	Building age[a] (yrs)	Ratio	NLExtract (2017)
Building structure	STR	Structure type	Nominal: STR_BRK = brick STR_CONC = concrete STR_STL = steel STR_WD = wooden STR_MXD = mixed	http://herbestemming.nu, http://boei.nl, http://nrpguldenfeniks.nl, http://sien-n.nl, http://cultureelerfgoed.nl, http://google.com/maps
Building shape	SHP	Building shape	Nominal: SHP_REC = square or rectangular SHP_CREC = compound rectangular (L or U-shape) SHP_CIR = circular SHP_OTH = other	http://google.com/maps
Building size	SIZE	Building size in floor area (m^2)	Ratio	http://planviewer.nl
Building height	HEIGHT	Building height in number of floors	Ratio	http://google.com/maps
Building length	LENGTH	Building length (m)	Ratio	http://planviewer.nl

Window area	WDOA	Amount of window area	Nominal: WDOA_NO = none WDOA_SM = small WDOA_MOD = moderate WDOA_LG = large	http://google.com/maps
Listed monument status	LSTMON	Listed monument status	Binary: 1 = yes, 0 = no	http://cultureelerfgoed.nl/, websites of municipalities and provinces
Site coverage	SITECVR	Building footprint to lot size ratio	Ratio	http://planviewer.nl
Site zoning	INDZN	Site with industrial zoning[a]	Binary: 1 = yes, 0 = no	http://ruimtelijkeplannen.nl
Location type	SAD	Surrounding address density[a] (1000 addresses/km^2)	Ratio	Statistics Netherlands (2017)
Conservation area	CONSA	Location in conservation area	Binary: 1 = yes, 0 = no	http://cultureelerfgoed.nl/
Location visibility	LOT	Lot type	Nominal: LOT_FL = flag lot LOT_INT = interior lot LOT_THRU = through lot LOT_COR = corner lot LO_MCOR = multi-corner lot	http://planviewer.nl
	DISRD	Distance to nearest fronting road (m)	Ratio	http://planviewer.nl
Location exposure	RD	Class of nearest fronting road	Nominal: RD_NO = no fronting road[b] RD_ACC = access road[c] RD_DISTR = distributor road RD_THRU = through road	http://planviewer.nl
Transport accessibility	DISBUS	Distance to nearest bus or tram stop (km)	Ratio	QGIS
	DISSTA	Distance to nearest station (km)	Ratio	QGIS
	DISHWY	Distance to nearest highway ramp (km)	Ratio	QGIS
Access to amenities	DISCITY	Distance to nearest city center (km)	Ratio	QGIS
	WTR50	Water body within 50 m	Binary: 1 = yes, 0 = no	http://google.com/maps
	GRN150	Public green space (>1 ha) within 150 m	Binary: 1 = yes, 0 = no	http://google.com/maps
Neighborhood demographics	STAT	Area status score of the 4-digit postal code area[a] (pts)	Ratio	Netherlands Institute for Social Research (2017)
Province	PR	Province location of the building	Nominal: PR_DR = Drenthe PR_FR = Friesland PR_GE = Gelderland PR_GR = Groningen PR_LI = Limburg PR_NB = North Brabant PR_NH = North Holland PR_OV = Overijssel PR_SH = South Holland PR_UT = Utrecht PR_ZE = Zealand	NLExtract (2017)

Note. Distances were measured as straight-line distances from the building.
[a] Reference year was 2017. [b] Including gated private roads, parking lot roads, restricted usage roads, and foot and bike paths.
[c] Including pedestrian shopping streets and squares.

4.3 Sampling

4.3.1 Population and sample

The target population consisted of historic industrial buildings in the Netherlands of 50 years or more (built no later than 1968) that were not in original use anymore. The lower age limit of 50 years was chosen in line with the Cultural Heritage Agency's former minimum age policy for listed buildings. Since it wasn't possible to identify all members of the population, a convenience sample was selected. Convenience sampling is a form of non-probability sampling where sample subjects are selected by convenience and availability. It is often used in situations where selecting a probability sample is difficult or impossible (Creswell & Creswell, 2018; Fraenkel et al., 2012). In convenience sampling, not all members of the population have an equal chance of being selected. The selected sample consisted of a case group of adaptively reused buildings and a control group of vacant buildings. As will be discussed in the next subsection, the sample buildings were selected from various publicly available sources. The sample size was determined using a rule of thumb. The rule of thumb is that there should be a minimum of 5 to 10 cases in the less frequent category of the dependent variable for each estimated variable (Peduzi, Concato, Kemper, Holford, & Feinstein, 1996; Vittinghoff & McCulloch, 2006). Since there were two dependent variable categories and 49 independent variables examined (see Section 5.1), the minimum sample size was determined at 490 buildings (2 x 5 x 49). As will be explained in the next subsection, the final sample included 518 buildings, equally divided into both sample groups. When sample groups have equal sizes, the statistical power is highest (Agresti, 2007; Cambell, Julious, & Altman, 1995).

4.3.2 Sampling frames

As discussed in the previous subsection, a convenience sample was used. The sampling frames for the case and control groups included various public sources, such as official websites and datasets. These sources including selection procedures are detailed below by sample group.

Case group sampling frames

The Herbestemming.nu website (http://www.herbestmming.nu), operated by the National Restoration Fund, provided a database of nearly 250 heritage adaptive reuse projects in the Netherlands, including those of industrial heritage.

The National Company for the Conservation, Development, and Exploitation of Industrial Heritage website (BOEi; http://www.boei.nl) provided a database of nearly 100 heritage adaptive reuse projects in the Netherlands, including those of industrial heritage.

The NRP Gulden Feniks website (http://www. nrpguldenfeniks.nl), operated by the National Restoration Platform, provided an overview of nearly 800 urban reuse projects in the Netherlands, including those of industrial heritage. The NRP Gulden Feniks is an annual award for the most outstanding renovation and transformation projects in the Netherlands.

All adaptively reused historic industrial buildings listed on these websites were recorded and cross-checked for duplicates as some buildings were listed on multiple websites. The buildings younger than 50 years were omitted and so were the buildings for which variables data were missing. After these selection procedures, 259 buildings were included in the final case group.

Control group sampling frames

The Addresses and Buildings key register (BAG) dataset (NLExtract, 2017) contained all lawful buildings in the Netherlands, including basic building information such as construction year, intended use, and occupancy status. All buildings of 50 years or more in the dataset with intended industrial use and a vacant or to-be-demolished status were recorded and explored in Google Maps (http://www.google.com/maps) to verify their industrial nature. This was because in the BAG dataset, the intended industrial use was also assigned to agricultural buildings and buildings with commercial kitchens. So, the buildings that were not industry-related were omitted. The remaining buildings were checked for absence of business activity in the Commercial Register (http://www.kvk/nl) to maximally ensure their vacancy. The buildings that proved to be in use were excluded and so were the buildings that proved to be vacant but for which variables data were missing. After these selection procedures, 102 buildings were added to the control group.

The Old Map of the Netherlands dataset (Dorp, Stad en Land, 2016) contained over 250 industrial buildings that were vacant during the national building inventory between 2006 and 2008 or were prone to become vacant in the following 10 years, as noted in Chapter 1. All buildings of 50 years or more in the dataset were recorded, and their presence and status were verified in the BAG dataset. The buildings with an in-use status in the BAG dataset were omitted and so were the buildings that were absent because they were assumed to be already demolished. The remaining buildings were cross-checked for duplicates and then checked for absence of business activity in the Commercial Register to maximally ensure their vacancy. The buildings that proved to be still in use were excluded and so were the buildings that proved to be vacant but for which variables data were missing. After these selection steps, 19 buildings were further added to the control group.

The Heemschut Heritage Association website (http://www.heemschut.nl) provided an overview of endangered heritage buildings in the Netherlands, including those of an industrial nature. All industrial heritage buildings of 50 years or more listed on the website were recorded and cross-checked for duplicates. The remaining buildings were checked for absence of business activity in the Commercial Register to maximally ensure their vacancy. The buildings that proved to be still in use were excluded and so were the buildings that proved to be vacant but for which variables data were missing. After these selection steps, 17 buildings were further added to the control group.

The Northern Netherlands Industrial Heritage Foundation website (SIEN-N; http://www.heemschut.nl) provided a database of over 130 industrial heritage buildings and structures in the provinces of Groningen, Friesland, and Drenthe. All buildings of 50 years or more with a vacant status in the database were recorded and cross-checked for duplicates. The remaining buildings were checked for absence of business activity in the Commercial Register to maximally ensure their vacancy. The buildings that proved to be still in use were excluded and so were the buildings that proved to be vacant but for which variables data were missing. After these selection procedures, 21 buildings were further added to the control group.

Ten urban exploration websites that were found through search engines (http://dolfing.net, http://lost-in-time-ue.nl, http://martintb.nl, http://pepperurbex.com, http://raym.deds.nl, http://urbanadventures.eu, http://urbanexploration.nl, http://http://verbodentoegang.eu, http://www.urbex.nl, http://www.zoomcity.nl) were consulted. Urban exploration websites are personal websites where urban explorers share brief information and pictures of visited abandoned places, including historic industrial buildings. All historic industrial buildings in the Netherlands shown on the consulted urban exploration websites were tracked in Google Maps and then checked for existence in the BAG dataset. The buildings that couldn't be tracked were omitted and so were the buildings that were absent in the BAG dataset. The remaining buildings were cross-checked for duplicates and then checked for absence of business activity in the Commercial Register to maximally ensure their vacancy. The buildings that proved to be still in use were excluded and so were the buildings that proved to be vacant but for which variables data were missing. After these selection procedures, 33 buildings were further added to the control group.

From the Herbestemming.nu, BOEi, and NRP Gulden Feniks websites, and various other websites found through search engines, another 67 buildings were selected following the selection procedures specified above. So, the final control group consisted of 259 buildings.

Figures 4.1 and 4.2 show the spatial distribution of the sampled adaptively reused and vacant buildings, respectively. The higher the concentration of buildings in an area, the bigger the size of the marker in the figures. As can be seen in the figures, there were no buildings sampled from the province of Flevoland (FL). This is probably a result of Flevoland only being officially established in 1985 after decades of land reclamation and, thus, having no buildings of the industrial age.

Figure 4.1. Spatial distribution of the sampled adaptively reused historic industrial buildings (n = 259).

Figure 4.2. Spatial distribution of the sampled vacant historic industrial buildings (n = 259).

4.4 Data collection

4.4.1 Attribute dataset

Data on the independent variables for each sample building were manually extracted from public secondary sources and populated in an attribute dataset created in Excel. Independent variables for which no data were available, were omitted. Sample buildings for which variables data were missing, were excluded too. The final dataset contained 259 cases of adaptively reused and 259 cases of vacant buildings. The dataset was believed to be the only one of its kind in the Netherlands.

4.4.2 Building attribute data

Data for the variables BLD (building type), AGE (building age), SIZE (building size), and STR (structure type) were extracted from the BAG dataset (NLExtract, 2017), and the Herbestemming.nu, BOEi, NRP Gulden Feniks, and SIEN-N websites. Data for the variables SHP (building shape), LENGTH (building length), HEIGHT (building height), and WDOA (amount of window area) were obtained from the Planviewer website (http://www.planviewer.nl), a web map service operated by the same name company, and from Google Maps. These two sources provided official cadastral maps and aerial and 3D maps from which the information was retrieved. Data for the variable LSTMON (listed monument status) were obtained from official websites of provinces and municipalities and the National Monuments Register (http://monumentenregister.cultureelerfgoed.nl), administered by the Cultural Heritage Agency (RCE).

4.4.3 Location attribute data

Data for the variables SITECVR (site coverage), LOT (lot type), RD (class of nearest fronting road), and DISRD (distance to nearest fronting road) were obtained from the Planviewer website. The website provided building footprints and lot sizes required to calculate the site coverage. The lot type, class of nearest fronting road, and distance to that road were retrieved from the provided cadastral and street maps. All roads on the street maps were color-coded such that through roads were orange, distributor roads were yellow, and access roads were white. Data for the variable CONSA (location in conservation area) were retrieved from conservation area maps on the RCE website (http://cultureelerfgoed.nl). Data for the variable INDZN (industrial zoning) were obtained from the Ruimtelijkeplannen.nl website (http://ruimtelijkeplannen.nl), the official website with zoning information and permitted land uses in the Netherlands. The website provided official zoning maps from which the zoning classifications were retrieved. Data for the variable SAD (surrounding address density) were obtained from Statistics Netherlands (2017). Data for the variables DISBUS (distance to nearest bus or tram stop), DISSTA (distance to nearest train station), DISHWY (distance to nearest highway ramp), and DISCITY (distance to nearest city center) were obtained from QGIS, a geographic information system developed by the Open Source Geospatial Foundation. Data for the variables WTR50 (waterbody within 50 m) and GRN150 (public green space within 150 m) were retrieved from Google Maps. Lastly, data for the variable STAT (area status score) were obtained from The Netherlands Institute for Social Research (SCP, 2017).

4.5 Data analysis

4.5.1 Data analysis methods

The data collected were analyzed using descriptive and inferential analyses in the Statistical Package for Social Sciences (SPSS). The descriptive analysis describes the data for variables through means, standard deviations, and frequencies but doesn't allow for conclusions to be drawn beyond the data analyzed. Inferential analysis, however, relates variables or compares groups in terms of variables allowing for inferences to be drawn from the sample to a population (Creswell & Creswell, 2018). Since the dependent variable was binary (whether a historic industrial building was adaptively reused or not), logistic regression was used for inferential analysis in SPSS. Logistic regression is, despite its name, a classification method for examining the effects of one or more independent variables on a binary dependent variable. Independent variables in logistic regression can be continuous and/or categorical. When categorical with more than two categories, the variable needs to be converted into a dummy variable. The categorical variable is then represented by k-1 dummy variables, where k stands for the number of categories and the kth category acts as the reference group (Osborne, 2015). Logistic regression predicts the probability of the dependent variable taking the value of 1 (or 0) by fitting the data to a logistic curve. For a given threshold value (usually 0.5), logistic regression classifies cases with a predicted probability higher than this value as one and cases with a lower predicted probability as zero (Agresti, 2007; Simonoff, 2003). As such, logistic regression diverts the dependent variable to a response variable that can be predicted by the independent variables. Two other classification methods available included decision trees and neural networks. Decision trees are tree-based models that can be used for predicting the class of a case. Each node represents a test on an attribute value, each branch represents the outcome of the test, and each leaf represents a class label. Although decision trees are known for their simplicity and transparency, they tend to overfit when they have too many nodes and, therefore, do not generalize well outside the training data (Rokach & Maimon, 2015). Neural networks are data-processing techniques inspired by biological neural networks in the brain. They have multiple applications, including classification. Each neuron is represented by a nonlinear, parameterized function of its input variables. So, a neural network is the composition of the nonlinear functions of two or more neurons (Dreyfus, 2005). Although neural networks may exceed decision trees in accuracy, decision trees are considered more comprehensible (Rokach & Maimon, 2015).

4.5.2 Data assumptions

Logistic regression makes several assumptions about the data. These assumptions are essential to building a good logistic model and are outlined below.

1. There should be a linear relationship between each continuous independent variable and the logit of the dependent variable (Osborne, 2015; Simonoff, 2003). Violation of this assumption can be overcome by converting the offending variable to another scale (square, logarithmic, inverse, etc.), though variable interpretation may become difficult. In severe cases, the offending variable(s) can be dichotomized (Tabachnick & Fidell, 2014). To assess linearity, the Box-Tidwell test (Box & Tidwell, 1962) was performed in SPSS. In this test, interaction terms between each

continuous variable and its natural log are added to the logistic regression model. If one or more interaction terms are statistically significant, the linearity assumption is violated.

2. There should be no multicollinearity between the independent variables (i.e., intercorrelations higher than 0.7). Multicollinear variables contain redundant information and inflate the error terms, resulting in unreliable beta coefficients (Agresti, 2007; Kleinbaum & Klein, 2010; Tabachnick & Fidell, 2014). Violation of this assumption can be overcome by removing the redundant variables. To assess multicollinearity, correlation tests were performed in SPSS.
3. There should be no outliers in the data. Outliers are poorly predicted cases that are actually in one category of the dependent variable but exhibit a high probability of being in the other category (Christensen, 1997; Tabachnick & Fidell, 2007). Violation of this assumption can be overcome by removing the offending cases (Hosmer, Lemeshow, & Sturdivant, 2013; Kleinbaum & Klein, 2010). To identify possible outliers, casewise diagnostics were requested in SPSS. Cases with an absolute standardized residual greater than 3 represent possible outliers. A standardized residual is the standardized difference between the observed and predicted probability of event occurrence (Hosmer et al., 2013; Simonoff, 2003).

4.5.3 Logistic model

The logistic model represents the probability P of event occurrence (or event non-occurrence), given the independent variables X. Therefore, the S-shaped curve for the logistic model can take any value between 0 and 1, as shown in Figure 4.3 (Sandeep, 2018). By transforming the logistic model to the logit model, the model is no longer limited to the 0-1 range but can take any value from $-\infty$ to $+\infty$, as shown in Figure 4.4 (Sandeep, 2018). The logistic model and the logit model are given by Equations 4.1 and 4.2 , respectively (or the other way around as maintained by some statisticians), where a is the intercept, and b_1, $b_2 \cdots b_p$ are the beta coefficients of the independent variables. The beta coefficient represents the change in ln(odds) of event occurrence for a unit increase in the corresponding independent variable. The odds are the ratio of the probability of event occurrence to the probability of event non-occurrence (Agresti, 2007; Simonoff, 2003). To arrive at the parameters, logistic regression uses maximum likelihood estimation. Maximum likelihood estimation is a method of estimating model parameters by maximizing a likelihood function so that

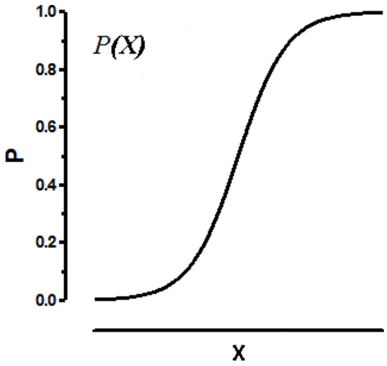


Figure 4.3. Logistic curve. Adapted from *Predictive analytics for controlling tax evasion* (p. 11), by S. Kumar, 2018, retrieved from https://raiith.iith.ac.in/4218 Copyright 2018 by Sandeep Kumar.

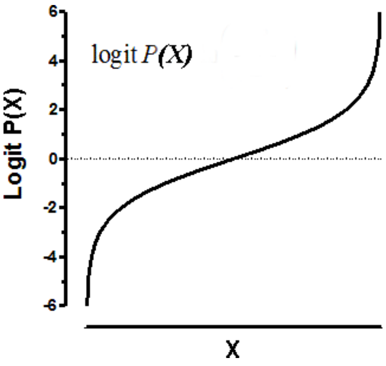


Figure 4.4. Logit curve. Adapted from *Predictive analytics for controlling tax evasion* (p. 11), by S. Kumar, 2018, retrieved from https://raiith.iith.ac.in/4218 Copyright 2018 by Sandeep Kumar.

under the assumed model the observed data is most probable (Kleinbaum & Klein, 2010). This method will be further discussed in Section 4.5.5.

$$P(X) = \frac{\mathrm{e}^{a + b_1x_1 + b_2x_2 + \ldots + b_px_p}}{1 + e^{a + b_1x_1 + b_2x_2 + \ldots + b_px_p}} \tag{4.1}$$

$$\text{Logit}\, P(X) = \ln\left(\frac{P(X)}{1-P(X)}\right) = a + b_1x_1 + b_2x_2 + \cdots + b_px_p \tag{4.2}$$

In retrospective studies, such as the one at hand, it is generally not possible to estimate true probabilities of event occurrence using only the observed data (Agresti, 2007; Simonoff, 2003). To still get the true probabilities, valid estimates of the intercept and the beta coefficients are required. A valid intercept estimate can only be obtained if the population proportion is known (Kleinbaum & Klein, 2010), which wasn't the case in the study. Valid estimates of the beta coefficients, however, can be obtained regardless of whether the study is prospective or retrospective. This is because the beta coefficients are the same in the conditional distributions of *Y* given *X* (in prospective studies) and *X* given *Y* (in retrospective studies).

4.5.4 Logistic regression parameters

While logistic models do have many applications, they lack the capability of dealing properly with the magnitudes of the model parameters. The numerical values of the beta coefficients can be discussed, but such interpretations may convey little beyond their direction and statistical significance. This limitation is mainly due to the non-linearity of the relationships established (Kaufman, 1996; Long, 1987). Therefore, several alternative statistics such as odds, ln(odds), odds ratios, ln(odds ratios), and probability changes have been proposed to ease interpretation. The odds ratio is the most used and indicates the change in odds of event occurrence for a unit increase in the corresponding independent variable. It is obtained by exponentiating the beta coefficient (Exp(*b*)) of the variable of interest (Agresti, 2007; Simonoff, 2003). Although the alternative statistics can provide more meaning to the relationships established, rather than relying only on the direction and significance of the coefficients, they cannot be used to compare the effects of different independent variables. This is because they describe changes in the independent and dependent variables by their natural metrics. To assess the relative magnitude of different independent variables, their scale needs to be standardized so that the amount of change in the dependent variable corresponds to a comparable difference in each independent variable, usually one standard deviation (Kaufman, 1996; Long, 1987). So far, little consideration has been given to standardized statistics in logistic regression. Analogous to the standardized regression coefficient in linear regression, Long (1987) came up with the standardized odds ratio. Kaufman (1996) proposed a variant of this metric, namely its natural logarithm form, and two other standardized statistics that use a probability metric. The standardized odds ratio indicates the change in odds of event occurrence for a standard deviation increase in the corresponding independent variable. It is obtained by taking the exponential of the product of the beta coefficient and the standard deviation of the corresponding variable (Exp(*bSD*)). Taking the natural logarithm of the standardized odds ratio gives the standardized beta coefficient (*bSD*). The standardized beta coefficient represents the change in the ln(odds) of event occurrence for a standard deviation increase in the corresponding independent variable. The higher the absolute value of the standardized beta coefficient, the stronger the effect of the independent variable on the dependent variable. It should be noted that while standardizing binary variables makes their interpretation vague (as they actually cannot be increased by a standard deviation), both Long and Kaufman suggested it for mathematical reasons. As it wasn't possible to estimate true adaptive reuse probabilities for the sampled buildings, the standardized probability coefficients by Kaufman will not be discussed here.

4.5.5 Logistic model fit

To evaluate how well a logistic model fits a set of data, generally, two approaches can be followed. The first approach involves assessing the goodness-of-fit of the model and the significance of the estimated parameters. The second approach involves computing measures of predictive power. These statistics measure how well the model predicts the dependent variable given the independent variables. They usually vary between 0 and 1, with higher values indicating better predictive power (Allison, 2014). The following are some goodness-of-fit statistics and measures of predictive power that (are reported by SPSS and) were used in the data analysis.

Maximized likelihood

The maximized likelihood (L) is the joined probability of obtaining the observed set of data. It is calculated as the product of the joined probability of the occurring events and the joined probability of the non-occurring events. Generally, the more parameters the alternative model has compared to the null model, the better it fits the data and the higher the maximized likelihood is (Kleinbaum & Klein, 2010). The maximized likelihood is required for the calculation of the -2log likelihood and the likelihood ratio, which will be discussed in the next paragraphs. The maximized likelihood function is shown in Equation 4.3, where $P(X_l)$ is the probability of getting the data for the lth occurring event, and $1 - P(X_l)$ is the probability of getting the data for the lth non-occurring event. The observed set of data is arranged into a first set of m_1 event occurrences and a subsequent set of $n - m_1$ event non-occurrences. The maximized likelihood function then returns the probability that the first m_1 observed events go with the event occurrences, given all possible arrangements of the n observed events into a set of m_1 event occurrences and a set of $n - m_1$ event non-occurrences.

$$L = \prod_{l=1}^{m_1} P(X_l) \prod_{l=m_1+1}^{n} [1 - P(X_l)] \tag{4.3}$$

Log-likelihood

The -2log likelihood ($-2LL$) is the product of -2 and the natural log of the maximized likelihood (L), as shown in Equation 4.4. The $-2LL$ is easier to compute than the maximized likelihood and is, therefore, more often used. Note that the larger the maximized likelihood of the alternative model compared to the null model, the smaller the $-2LL$, and the better the model fit. Therefore, the $-2LL$ denotes the lack of goodness-of-fit because the larger it gets, the less well the model fits (Osborne, 2015). The $-2LL$ is also used to compute the likelihood ratio.

$$-2LL = -2\ln(L) \tag{4.4}$$

Likelihood ratio (chi-square)

The likelihood ratio (*LR*) compares the -2log likelihoods (-2*LL*) for two competing models, the null and the alternative models. The *LR* is calculated as -2 times the natural log of the ratio of the maximized likelihood for the null model (L_0) to the maximized likelihood for the alternative model (L_M), as shown in Equation 4.5. The *LR* can also be expressed as the difference of the -2*LL* for the null model and the -2*LL* for the alternative model. For large samples, the *LR* has an approximate chi-square distribution with degrees of freedom equal to the number of beta coefficients set to zero in the null model. These parameters specify the null hypothesis being tested. Regardless of which two models are compared, the *LR* will yield a value between 0 and +∞, with a higher value indicating a higher significance of the corresponding coefficients (Kleinbaum & Klein, 2010; Osborne, 2015).

$$LR = -2\ln\left(\frac{L_0}{L_\mathrm{M}}\right) = -2\ln(L_0) - 2\ln(L_\mathrm{M}) \tag{4.5}$$

Wald statistic

The Wald statistic (Wald) is used to test the significance of an independent variable in the model. It is defined by the ratio of the beta coefficient to its standard error, as shown in Equation 4.6. When squared, the Wald has a chi-square distribution with one degree of freedom. In large samples, both the Wald χ^2 and the likelihood ratio will give approximately the same value, while in small samples they might give different values (Kleinbaum & Klein, 2010). So, the higher the Wald χ^2, the higher the significance of the variable, and the more the variable contributes to the model.

$$\text{Wald}\,\chi^2 = \left(\frac{B}{SE}\right)^2 \tag{4.6}$$

Pseudo R-squared

The coefficient of determination, commonly known as the R-squared (R^2), is the most used measure of predictive power. Unlike the R^2 in linear regression which measures the proportion of variance explained, in logistic regression, there is no such equivalent (Allison, 2014; Osborne, 2015). Therefore, several pseudo-R^2 measures have been proposed. They represent the improvement in model likelihood over the null model (Hemmert, Schons, Wieseke, & Schimmelpfennig, 2018). The Cox & Snell R^2 and the Nagelkerke R^2 are the two pseudo R^2 measures reported by SPSS. The Cox & Snell R^2 is based on the ratio of the log-likelihood for the alternative model to the log-likelihood for the null model. Its disadvantage is that it has an upper bound value of less than 1. The Nagelkerke R^2, on the other hand, is a modified version of the Cox & Snell R^2 that can take any value ranging from 0 to 1. Both measures are shown in Equations 4.7 and 4.8, where L_0 is the maximized likelihood for the null model, L_M is the maximized likelihood for the alternative model, and n is the sample size. Note that the larger the n, the larger the pseudo R^2, and the better the prediction.

$$R^2_\mathrm{CS} = 1 - \left(\frac{L_0}{L_\mathrm{M}}\right)^{\frac{2}{n}} \tag{4.7}$$

$$R^2_\mathrm{Nag} = \frac{1-\left(\frac{L_0}{L_\mathrm{M}}\right)^{\frac{2}{n}}}{1-L_0^{\frac{2}{n}}} \tag{4.8}$$

Classification table

The classification table is a two-by-two table that shows the predictive power of a logistic model. The table cross-classifies the observed values for the dependent variable ($Y = 0$ or 1) and the predicted values ($Y' = 0$ or 1). As mentioned earlier, the predicted values are obtained by classifying predicted probabilities higher than a given threshold (usually 0.5) as one and those lower as zero. The cell frequencies in Table 4.2 show the number of true positives (n_{TP}) and false negatives (n_{FN}) out of the number of true event occurrences (n_1) and also the number of false positives (n_{FP}) and true negatives (n_{TN}) out of the number of true event non-occurrences (n_0). The number of true positives and true negatives are the correctly predicted event occurrences and non-occurrences, respectively. The number of false positives and false negatives are the incorrectly predicted event occurrences and non-occurrences, respectively. Summaries of predictive power from the classification table include the sensitivity, specificity, and the overall proportion of correct classifications (Agresti, 2007). The sensitivity is calculated as the ratio of the true positives to the true event occurrences (n_{TP}/n_1), the specificity as the ratio of the true negatives to the true event non-occurrences (n_{TN}/n_0), and the overall proportion of correct classifications as the ratio of the sum of the true positives and true negatives to the sum of the true event occurrences and true event non-occurrences $(n_{TP} + n_{TN})/(n_1 + n_0)$. For a given threshold, the closer the specificity and sensitivity are to one, the better the model predicts (Kleinbaum & Klein, 2010).

Table 4.2

Classification table

Observed	Predicted		
	$Y' = 0$	$Y' = 1$	
$Y = 0$	n_{TN}	n_{FP}	n_0
$Y = 1$	n_{FN}	n_{TP}	n_1

4.6 Research validity

4.6.1 Internal validity

The case-control design introduced threats to the internal validity of the study. Internal validity relates to the extent to which the observed effects of the independent variables on the dependent variable truly reflect the causal effects between these variables in the form in which they were measured or manipulated (Babbie, 2010; Shadish et al., 2002). Case-control studies are low in internal validity because they cannot directly manipulate an independent variable to determine its effect on the dependent variable. This is because case-control studies are retrospective and thus look back in time from the outcome to the possible causes. At the start of the study, the sampled buildings were already adaptively reused or vacant, and thus there is no claim of causation.

The internal validity of the study is further limited by possible confounding introduced by the non-probability sampling method. In other words, the observed effects may have been biased by unmeasured confounding variables. Confounding bias can be reduced at the design stage by matching subjects from sample groups on the confounding variables, but this can be difficult and wasteful of resources. Often, the confounding variables are unknown before the study starts, and many times matches cannot be found for all subjects, resulting in the reduction of the sample size (Fraenkel et al., 2012; McNamee, 2005; Salkind, 2010). For these reasons, matching wasn't used in the study at hand. At the analysis stage, confounding bias can be reduced through statistical adjustment techniques such as stratification and multiple regression analysis. Stratification is the partitioning of sample groups into homogeneous strata that represent various levels of the confounding variable in order to eliminate the confounding effect within strata. But often, as mentioned above, the confounding variables are unknown before the study starts. Also, the more strata there are, the smaller the size of each stratum becomes, and the less stable the within-stratum estimation becomes. Therefore, the number of confounding variables that can be controlled for by stratification is limited. In multiple regression analysis, the number of potentially confounding variables that can be controlled for can be quite large. Multiple regression allows for the estimation of the effect of a given independent variable on the dependent variable holding all other variables constant. As such, it provides a way of controlling for potentially confounding variables in the model (McNamee, 2005; Salkind, 2010). The study used logistic regression as the method of analysis. Because not all potential factors of adaptive reuse were included in the analysis (some were omitted and some were not the focus of the study), some risk of confounding remains.

The internal validity is also affected by the inability to filter the length of the vacancy period due to a lack of data on this aspect. Therefore, the control group included vacant buildings with various lengths of vacancy period. Especially structural vacant buildings (i.e., buildings that have been vacant for more than 3 years without any prospect of future occupancy) are troublesome (Keeris, 2007) and would thus have alone made better control candidates.

Lastly, the study relied in part on maps and images provided by web map services such as Google Maps and Planviewer. These maps and images were not always clear and up to date, so there is no claim of 100 percent accuracy. This further limits the internal validity of the study.

4.6.2 External validity

The non-probability sampling introduced a threat to the external validity of the study. External validity relates to the extent to which study results can be generalized to other persons or things, other settings, or past or future situations (Babbie, 2010; Creswell & Creswell, 2018). Due to the non-probability sampling, the sample may not have been representative of the population and thus may have limited the generalizability of the results. To limit this threat, buildings were selected from sources with national and regional coverage. In addition, buildings selected from these sources were not discarded without reasonable justification, meaning that all historic industrial buildings listed in these sources had an equal chance of being selected. A second threat was introduced by the sample proportion possibly being different from the population proportion. Consequently, the estimated probabilities of adaptive reuse may not correspond to the real probabilities. Although this threat doesn't affect the beta coefficients, some caution is needed when generalizing these results.

4.7 Summary

This chapter discussed the methodology used to empirically determine building and location factors affecting industrial heritage adaptive reuse in the Netherlands. For this end, a case-control design was employed. Case-control studies seek to identify possible causal factors of an event by retrospectively comparing two existing groups that differ in the outcome of the event. The outcome variable was defined as whether or not a historic industrial building was adaptively reused and 49 independent variables were derived from building and location attributes identified in the literature review as important factors of (industrial heritage) adaptive reuse. Based on the research design, a non-probability sample of 518 historic industrial buildings, equally divided into a case group of adaptively reused buildings and a control group of vacant buildings, was selected. Data collection was performed through secondary data manually extracted from publicly available sources. To assist in this process, a building and location attribute dataset was created. Logistic regression was used to analyze the data. Logistic regression is a classification method for examining the effects of one or more independent variables on a binary dependent variable. The retrospective and non-probability sampling design introduced threats to the internal and external validity of the study. Therefore, some caution is needed when generalizing the study results.

5 Empirical Results

This chapter presents the empirical results of the conducted study. The first section provides descriptive statistics for the sample data, the second section discusses the assumption tests on the data, and the third and last section outlines the findings of the logistic regression analyses.

5.1 Descriptive statistics

The sample consisted of 518 historic industrial buildings in the Netherlands of 50 years or more, equally divided into the case group (adaptively reused) and control group (vacant). Descriptive statistics provided basic sample information, highlighting the possible effects of the independent variables on the dependent variable. These statistics are further discussed below.

5.1.1 Continuous variables

Table 5.1 shows the mean values of the 12 continuous independent variables for the total sample and each sample group (adaptively reused and vacant). The table also shows percentage mean differences and t-test statistics. The t-test determines if there is a significant difference between the means of two unrelated groups for a continuous variable, and the t-test statistic or t-value measures the size of the difference relative to the variation in the data. The higher the t-value, the larger the difference between the two groups (Salkind, 2010). Although mean values and t-values are generally calculated for normally distributed data, no normal distribution was assumed due to non-probability sampling. The data in Table 5.1 suggest that the groups significantly differed on all continuous variables except on LENGTH. The groups differed the most on SAD. Also notable is that STAT was more than twice as high for the vacant buildings than for the adaptively reused buildings, and SIZE was almost twice as large for the adaptively reused buildings than for the vacant buildings.

Table 5.1

Mean values, mean differences, and t-test statistics

Variable (description; unit)	Total sample (*N* = 518)		Vacant (*n* = 259)		Reused (*n* = 259)		% Mean difference	T-value (equal variance)
	Mean	*SD*	Mean	*SD*	Mean	*SD*		
AGE (building age; yrs)	101.49	43.45	96.70	44.01	106.28	42.42	9.9%	-2.522*
SIZE (building size; m^2)	2844.97	5022.38	1915.00	4373.95	3774.95	5447.81	97.1%	-4.284**
HEIGHT (building height; fl.)	2.42	2.19	1.95	1.92	2.88	2.35	47.7%	-4.935**
LENGHT (building length; m)	31.21	26.79	30.03	28.45	32.40	25.01	7.9%	-1.007
SITECVR (site coverage; ratio)	0.46	0.29	0.39	0.26	0.54	0.30	38.5%	-5.949**
SAD (surrounding address density; 1000 addresses/km^2)	1.80	1.72	1.26	1.29	2.35	1.91	86.3%	-7.601**
DISRD (distance to nearest fronting road; m)	45.65	89.09	57.22	111.45	34.08	56.72	-40.4%	2.977**
DISBUS (distance to nearest bus or tram stop; km)	0.30	0.38	0.35	0.40	0.25	0.34	-28.6%	3.101**
DISSTA (distance to nearest train station; km)	3.36	4.44	4.74	5.16	1.97	2.99	-58.4%	7.468**

DISHWY (distance to nearest highway ramp; km)	4.33	4.71	5.37	5.88	3.29	2.78	-38.7%	5.159**
DISCITY (distance to nearest city center; km)	14.67	17.71	16.81	18.35	12.52	16.81	-25.5%	2.775**
STAT (area status score; pts)	-0.39	1.20	-0.25	1.08	-0.52	1.31	-108.0%	2.545*

**. Group means are statistically significantly different at the 0.01 level (2-tailed).
*. Group means are statistically significantly different at the 0.05 level (2-tailed).

5.1.2 Categorical variables

Before running descriptive statistics, the categorical independent variables BLD (building type), STR (structure type), SHP (building shape), WDOA (amount of window area), LOT (lot type), RD (class of nearest fronting road), and PR (province location) were dummy-coded. This brought the total number of binary categorical variables to 37. Table 5.2 shows frequencies and percentages of these variables for the total sample and each sample group (adaptively reuse and vacant). The table also shows percentages of adaptively reused buildings by variable. While notably, WDO_NO (no window area) was 21 times more frequent among the vacant buildings than among the adaptively reused buildings, care should be taken when interpreting this result as the number of adaptively reused buildings without window area (n=1) was quite low compared to the number of vacant buildings without window area (n=21). The same goes for STR_WD (wooden structure) and PR_ZE (location in Zealand). Also noteworthy is that LOT_MCOR (multi-corner lot) was more than three times more frequent among the adaptively reused buildings than among the vacant buildings.

Table 5.2.

Frequencies and percentages of binary categorical variables

Variable	Total sample (N = 518)		Vacant (n = 259)		Reused (n = 259)		% Reused
	Frequency	% Total	Frequency	% Total	Frequency	% Total	
BLD_FAC[a] (factory building)	211	40.7%	91	35.1%	120	46.3%	56.9%
BLD_NRG (energy-supply building)	49	9.5%	20	7.7%	29	11.2%	59.2%
BLD_WH (warehouse building)	99	19.1%	64	24.7%	35	13.5%	35.4%
BLD_WS (workshop building)	50	9.7%	24	9.3%	26	10.0%	52.0%
BLD_WTR (water-supply building)	30	5.8%	18	6.9%	12	4.6%	40.0%
BLD_OTH (other building type)	79	15.3%	42	16.2%	37	14.3%	46.8%
STR_BRK[a] (brick structure)	166	32.0%	88	34.0%	78	30.1%	47.0%
STR_CONC (concrete structure)	122	23.6%	45	17.4%	77	29.7%	63.1%
STR_STL (steel structure)	97	18.7%	55	21.2%	42	16.2%	43.3%
STR_WD (wooden structure)	16	3.1%	14	5.4%	2	0.8%	12.5%
STR_MXD (mixed structure)	117	22.6%	57	22.0%	60	23.2%	51.3%
SHP_REC[a] (square or rectangular shape)	291	56.2%	152	58.7%	139	53.7%	47.8%
SHP_CREC (compound rectangular shape)	138	26.6%	69	26.6%	69	26.6%	50.0%
SHP_CIR (circular shape)	18	3.5%	10	3.9%	8	3.1%	44.4%
SHP_OTH (other shape)	71	13.7%	28	10.8%	43	16.6%	60.6%
WDOA_NO (no window area)	22	4.2%	21	8.1%	1	0.4%	4.5%
WDOA_SM (small window area)	159	30.7%	104	40.2%	55	21.2%	34.6%
WDOA_MOD[a] (moderate window area)	277	53.5%	119	45.9%	158	61.0%	57.0%
WDOA_LG (large window area)	60	11.6%	15	5.8%	45	17.4%	75.0%
LSTMON (listed monument status)	212	40.9%	64	24.7%	148	57.1%	69.8%

INDZ (site with industrial zoning)	233	45.0%	169	65.3%	64	24.7%	27.5%
CONSA (location in conservation area)	52	10.0%	25	9.7%	27	10.4%	51.9%
LOT_FL (flag lot)	112	21.6%	64	4.2%	48	18.5%	42.9%
LOT_INT[a] (interior lot)	224	43.2%	127	49.0%	97	37.5%	43.3%
LOT_THRU (through lot)	41	7.9%	14	5.4%	27	10.4%	65.9%
LOT_COR (corner lot)	92	17.8%	43	16.6%	49	18.9%	53.3%
LOT_MCOR (multi-corner lot)	49	9.5%	11	4.2%	38	14.7%	77.6%
RD_NO (not fronting a road)	95	18.3%	59	22.8%	36	13.9%	37.9%
RD_ACC[a] (fronting an access road)	268	51.7%	112	43.2%	156	60.2%	58.2%
RD_DISTR (fronting a distributor road)	134	25.9%	72	27.8%	62	23.9%	46.3%
RD_THRU (fronting a through road)	21	4.1%	16	6.2%	5	1.9%	23.8%
WTR50 (water body within 50 m)	200	38.6%	103	39.8%	97	37.5%	48.5%
GRN150 (public green space within 150 m)	65	12.5%	33	12.7%	32	12.4%	49.2%
PR_DR (location in Drenthe)	10	1.9%	6	2.3%	4	1.5%	40.0%
PR_FR (location in Friesland)	24	4.6%	14	5.4%	10	3.9%	41.7%
PR_GE (location in Gelderland)	84	16.2%	39	15.1%	45	17.4%	53.6%
PR_GR (location in Groningen)	45	8.7%	38	14.7%	7	2.7%	15.6%
PR_LI (location in Limburg)	30	5.8%	9	3.5%	21	8.1%	70.0%
PR_NB[a] (location in North Brabant)	101	19.5%	50	19.3%	51	19.7%	50.5%
PR_NH (location in North Holland)	61	11.8%	22	8.5%	39	15.1%	63.9%
PR_OV (location in Overijssel)	49	9.5%	14	5.4%	35	13.5%	71.4%
PR_SH (location in South Holland)	68	13.1%	44	17.0%	24	9.3%	35.3%
PR_UT (location in Utrecht)	32	6.2%	10	3.9%	22	8.5%	68.8%
PR_ZE (location in Zealand)	14	2.7%	13	5.0%	1	0.4%	7.1%

[a] Reference categories for dummy-coded categorical variables.

5.2 Assumption tests

Before conducting the logistic regression analyses, assumption tests were performed to check for linearity, multicollinearity, and outliers. All tests were nonparametric because no normal distribution was assumed. It should, however, be noted that logistic regression itself doesn't require the data to be normally distributed. The tests were conducted using SPSS.

5.2.1 Linearity

The Box-Tidwell Test (Box & Tidwell, 1962) was performed to test for a linear relationship between the 12 continuous independent variables and the logit of the dependent variable. Therefore, a logistic regression model was run with all 49 independent variables, the intercept, and 12 interaction terms between the continuous independent variables and their natural logs. Before log transformation, the values of STAT (area status score) were added by a constant value to correct for negative and zero values. Although it is not common to correct the statistical alpha level ($\alpha = .05$) when testing multiple hypotheses, Tabachnick and Fidell (2014) suggested applying a Bonferroni correction when assessing the linearity assumption in logistic regression. The Bonferroni correction compensates for the increase in the chance of rejecting a null hypothesis when performing multiple tests. The alpha level is then divided by the number of terms in the model. Applying the Bonferroni correction resulted in statistical significance being accepted when $p <$

.000806. The test results in Appendix A show that the interaction term for DISSTA (distance to nearest station) was statistically significant (p = .000003). To address this violation, DISSTA was square transformed into DISSTASQ. The second test results in Appendix B show that none of the interaction terms were statistically significant, indicating that the linearity violation was overcome.

5.2.2 Multicollinearity

Multicollinearity between the 12 continuous independent variables was assessed using the Spearman rank-order correlation test. Spearman's correlation (ρ) is a nonparametric measure of the monotonic correlation between two ranked variables. It is used instead of the Pearson correlation when the assumptions of normality, homoscedasticity, and linearity are not met (Sprinthall, 2014). Before conducting the test, the values of the continuous variables were ranked, where the highest value was assigned a rank of 1. The test results in Appendix C show no high correlations (above 0.7) between the ranked variables.

Multicollinearity between the 37 binary independent variables was assessed using the phi correlation test. The phi correlation (φ) is a nonparametric measure of the correlation between two binary variables (Tabachnick & Fidell, 2014). The test results in Appendix D show no high correlations (above 0.7) between the binary variables.

Multicollinearity between the continuous and binary independent variables was assessed using the rank-biserial correlation test. The rank-biserial correlation (r) is a nonparametric measure of the monotonic correlation between a binary and a ranked variable (Cureton, 1956). The test results in Appendix E show no high correlations (above 0.7) between the binary and ranked variables.

5.2.3 Outliers

To test for outliers in the data, a logistic regression model with all independent variables was run, and casewise diagnostics were requested. The threshold for defining outliers was set at 3 standard deviations. The casewise diagnostics revealed no cases with an absolute standardized residual greater than 3 standard deviations. Therefore, all 518 cases were kept in the analysis.

5.3 Logistic models

To assess the effects of the independent building and location variables on adaptive reuse, logistic regression analyses were conducted. A null model and three alternative logistic models were successively fitted to the data. The second and third models assessed the effects of the building and location variables, respectively. The fourth model assessed the effects of both the building and location variables on adaptive reuse. The variables were added stepwise to the models. The forward stepwise procedure adds at each step the most significant ($p < .05$) variable to the model until none of the variables left out of the model would have a statistically significant contribution if added to the model. It should be noted that the stepwise procedure doesn't consider all possible models and is thus not guaranteed to identify the optimal model. The following sections discuss the four models, particularly the fourth one. Tables 5.5, 5.8, and 5.11 show model results for the independent variables in the second, third, and fourth models, respectively. The tables include the beta coefficient ("*b*" column), the standard error of the beta coefficient ("*SE*" column), the standard deviation ("*SD*" column), the standardized beta coefficient ("*bSD*" column), the Wald statistic ("Wald" column), the degree of freedom for the Wald statistic ("*df*" column), the level of statistical significance ("Sig." column), and the odds ratio ("Exp(*b*)" column).

5.3.1 Model 1

The first model was the null model, which included only the intercept. The model had a -2log likelihood of 718.1 and correctly classified 50% of cases, with a sensitivity of 0% and specificity of 100%. The sensitivity is the ratio of the true positives (values predicted to be 1 that were 1) to the true event occurrences (values that were 1). The specificity is the ratio of the true negatives (values predicted to be 0 that were 0) to the true event non-occurrences (values that were 0).

5.3.2 Model 2

The second model tested the effects of the independent building variables. The model was statistically significant ($\chi^2(6) = 116.349$, $p < .001$) and improved the -2log likelihood of the null model from 718.1 to 601.751, as shown in Table 5.3. The improvement in likelihood ranged from 20.1% to 26.8%, as shown by the Cox & Snell R^2 and Nagelkerke's R^2 in the table. The model correctly classified 69.9% of cases, with a sensitivity of 72.2% and specificity of 67.6%, as shown in Table 5.4.

Table 5.3

Summary for Model 2

Step	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
6	601.751	.201	.268

Table 5.4

Classification table for Model 2

Observed	Predicted		% Correct
	REUSED = 0	REUSED = 1	
REUSED = 0	175	84	67.6
REUSED = 1	72	187	72.2
Overall %			69.9

Note. The cut value is .500

Table 5.5 shows that six of the 20 independent building variables that were stepwise tested in the model reached statistical significance and remained in the final model. Most notable is that LSTMON (listed monument status) had the highest absolute standardized beta coefficient (0.652) and Wald statistic (41.839), indicating the highest effect and significance in the model, respectively.

Table 5.5

Variables in Model 2

	b	*SE*	*SD*	*bSD*	Wald	*df*	Sig.	Exp(*b*)
STR_CONC (concrete structure)	0.498	0.241	0.425	0.212	4.291	1	.038	1.646
STR_WD (wooden structure)	-1.726	0.810	0.173	-0.299	4.546	1	.033	0.178
SIZE (building size)	0.00005	0.000	5022.384	0.251	4.549	1	.033	1.00005
WDOA_NO (no window area)	-2.644	1.038	0.202	-0.534	6.489	1	.011	0.071
WDOA_SM (small window area)	-0.896	0.216	0.462	-0.414	17.152	1	.000	0.408
LSTMON (listed monument status)	1.325	0.205	0.492	0.652	41.839	1	.000	3.762
Intercept	-0.404	0.166	-	-	5.951	1	.015	0.668

5.3.3 Model 3

The third model tested the effects of the independent location variables. The model was statistically significant ($\chi^2(13) = 219.712$, $p < .001$) and improved the -2log likelihood of the null model from 717.1 to 497.388, as shown in Table 5.6. The improvement in likelihood ranged from 34.7% to 46.3%, as indicated by the Cox & Snell R^2 and Nagelkerke's R^2 in the table. The model correctly classified 79.0% of cases, with a sensitivity of 84.9% and specificity of 73.0%, as shown in Table 5.7.

Table 5.6

Summary for Model 3

Step	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
13	497.388	.347	.463

Table 5.7

Classification table for Model 3

Observed	Predicted		% Correct
	REUSED = 0	REUSED = 1	
REUSED = 0	189	70	73.0
REUSED = 1	39	220	84.9
Overall %			79.0

Note. The cut value is .500

Table 5.8 shows that 13 of the 29 independent location variables that were stepwise tested in the model reached statistical significance and remained in the final model. Most notable is that INDZN (site with industrial zoning) had the highest absolute standardized beta coefficient (0.962) and Wald statistic (60.161), indicating the largest effect and highest significance in the model, respectively.

Table 5.8

Variables in Model 3

	b	*SE*	*SD*	*bSD*	Wald	*df*	Sig.	Exp(*b*)
INDZN (site with industrial zoning)	-1.932	0.249	0.498	-0.962	60.161	1	.000	0.145
SAD (surrounding address density)	0.357	0.092	1.716	0.613	15.044	1	.000	1.429
LOT_MCOR (multi-corner lot)	1.225	0.413	0.293	0.359	8.801	1	.003	3.403
RD_THRU	-1.587	0.605	0.197	-0.313	6.874	1	.009	0.205
DISHWY (distance to nearest highway ramp)	-0.072	0.031	4.710	-0.339	5.607	1	.018	0.930
STAT (area status score)	-0.327	0.099	1.203	-0.393	10.983	1	.001	0.721
PR_GE (location in Gelderland)	0.856	0.333	0.369	0.316	6.587	1	.010	2.353
PR_GR (location in Groningen)	-1.037	0.528	0.282	-0.292	3.867	1	.049	0.354
PR_LI (location in Limburg)	1.427	0.514	0.234	0.334	7.711	1	.005	4.166
PR_NH (location in North Holland)	0.962	0.394	0.323	0.311	5.963	1	.015	2.616
PR_OV (location in Overijssel)	1.576	0.433	0.293	0.462	13.216	1	.000	4.833
PR_SH (location in South Holland)	-0.828	0.421	0.338	-0.280	3.864	1	.049	0.437
PR_UT (location in Utrecht)	1.910	0.483	0.241	0.460	15.604	1	.000	6.751
Intercept	-0.112	0.323	-	-	0.121	1	.728	0.894

5.3.4 Model 4

The fourth model tested the effects of both the independent building and location variables. The model was statistically significant ($\chi^2(17) = 282.62$, $p < .001$) and improved the -2log likelihood of the null model from 717.1 to 434.480, as shown in Table 5.9. The improvement in likelihood ranged from 42.2% to 56.2%, as indicated by the Cox & Snell R^2 and the Nagelkerke's R^2. The model correctly classified 82.4% of cases, with a sensitivity of 84.9% and specificity of 79.9%, as shown in Table 5.10. The second and third models correctly classified 69.9% and 79.0% of cases, respectively, with a sensitivity of 72.2% and 84.9%, respectively, and a specificity of 67.6% and 73.0%, respectively.

Table 5.9

Summary for Model 4

Step	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
17	434.480	.422	.562

Table 5.10

Classification table for Model 4

Observed	Predicted		% Correct
	REUSED = 0	REUSED = 1	
REUSED = 0	207	52	79.9
REUSED = 1	39	220	84.9
Overall %			82.4

Note. The cut value is .500

Table 5.11

Variables in Model 4

	b	*SE*	*SD*	*bSD*	Wald	*df*	Sig.	Exp(*b*)
AGE (building age)	0.009	0.003	43.446	0.391	7.436	1	.006	1.009
STR_WD (wooden structure)	-2.575	0.944	0.173	-0.445	7.444	1	.006	0.076
WDOA_NO (no window area)	-2.216	1.093	0.202	-0.448	4.115	1	.043	0.109
WDOA_SM (small window area)	-0.916	0.264	0.462	-0.423	12.058	1	.0005	0.400
LSTMON (listed monument status)	1.330	0.265	0.492	0.654	25.283	1	.000	3.781
INDZN (lot with industrial zoning)	-1.596	0.271	0.498	-0.795	34.611	1	.000	0.203
SAD (surrounding address density)	0.314	0.098	1.716	0.539	10.192	1	.001	1.370
LOT_MCOR (multi-corner lot)	1.114	0.448	0.293	0.326	6.182	1	.013	3.046
RD_THRU (fronting a through road)	-1.900	0.696	0.197	-0.374	7.449	1	.006	0.150
DISHWY (distance to nearest highway ramp)	-0.084	0.033	4.710	-0.396	6.407	1	.011	0.919
STAT (area status score)	-0.434	0.106	1.203	-0.522	16.741	1	.000	0.648
PR_GR (location in Groningen)	-1.856	0.551	0.282	-0.523	11.325	1	.0008	0.156
PR_LI (location in Limburg)	1.157	0.543	0.234	0.271	4.531	1	.033	3.180
PR_NH (location in North Holland)	1.004	0.422	0.323	0.324	5.667	1	.017	2.730
PR_OV (location in Overijssel)	1.419	0.437	0.293	0.416	10.529	1	.001	4.135
PR_SH (location in South Holland)	-1.499	0.450	0.338	-0.507	11.124	1	.0009	0.223
PR_UT (location in Utrecht)	1.609	0.515	0.241	0.388	9.765	1	.002	4.997
Intercept	-0.917	0.495	-	-	3.429	1	.064	0.400

Table 5.11 shows that of the total 49 independent building and location variables that were stepwise tested in the model, 17 reached statistical significance and remained in the final model. Of these, five were building variables and 12 were location variables. These variables are discussed below.

AGE (building age) showed a positive effect on adaptive reuse such that for every year increase in building age, the odds of adaptive reuse were 1% higher (*OR* = 1.009). This is in line with the descriptive statistics but contradicts the literature review, which suggested that older buildings would be less prone to adaptive reuse. AGE wasn’t evident in Model 2.

The dummy variable STR_WD (wooden structure) had a negative effect on adaptive reuse, with the odds being 92% lower (*OR* = 0.076) when compared to structures of other materials. While this is consistent with the Model 2 results, the descriptive statistics, and the literature review, care should be taken when interpreting this result as the observed case numbers for STR_WD were quite low among the adaptively reused buildings (n=2) compared to the vacant buildings (n=14). This was also reflected in the high standard error of the beta coefficient (0.944).

The dummy variables WDOA_NO (no window area) and WDOA_SM (small window area), too, had a negative effect on adaptive reuse, with the odds being 89% (*OR* = 0.109) and 60% (*OR* = 0.4), respectively, lower when compared to larger window areas. These findings are in line with the Model 2 results, the descriptive statistics, and the literature review. However, care should be taken when interpreting these results as the observed case numbers for WDOA_NO were quite low among the adaptively reused buildings (n=1) compared to the vacant buildings (n=21). This was also reflected in the high standard error of the beta coefficient (1.093).

LSTMON (listed monument status) showed the second strongest and positive effect on adaptive reuse, with a standardized beta coefficient of 0.654 and Wald statistic of 25.283. The odds of adaptive reuse were 278% higher (*OR* = 3.781) when compared to no listed status. These findings are consistent with the Model 2 results, the descriptive statistics, and some of the literature reviewed. The findings, however, challenge other parts of the literature review that suggested that a listed status would discourage adaptive reuse.

INDZN (site with industrial zoning) had the strongest and negative effect on adaptive reuse, with a standardized beta coefficient of -0.795 and Wald statistic of 34.611. The odds of adaptive reuse were 80% lower (*OR* = 0.203) when compared to sites with other zoning designations. These findings are in line with the Model 3 results, the descriptive statistics, and the literature review.

SAD (surrounding address density) showed the third strongest and positive effect on adaptive reuse, with a standardized beta coefficient of 0.539 and a Wald statistic of 10.192. For every increase of 1000 addresses in SAD, the odds of adaptive reuse were 37% higher (*OR* = 1.370). These findings are in line with the Model 3 results, the descriptive statistics, and the literature review.

The dummy variable LOT_MCOR (multi-corner lot), too, showed a positive effect on adaptive reuse, with the odds being 205% higher (*OR* = 3.046) when compared to other types of lots. This is in line with the Model 3 results, the descriptive statistics, and the literature review.

The dummy variable RD_THRU (fronting a through road) had a negative effect on adaptive reuse, with the odds being 85% lower (*OR* = 0.15) than when fronting lower-class roads and not fronting a road. This is in line with the Model 3 results, the descriptive statistics, and some of the literature reviewed. The finding, however, contradicts other parts of the literature review that suggested that locations along higher-class roads would be more conducive to adaptive reuse.

DISHWY (distance to nearest highway ramp), too, had a negative effect on adaptive reuse such that for every kilometer increase in this distance, the odds of adaptive reuse were 8% lower (*OR* = 0.919). This is consistent with the Model 3 results, the descriptive statistics, and the literature review.

STAT (area status score), too, had a negative effect on adaptive reuse such that for every point increase in this score, the odds of adaptive reuse were 35% lower (*OR* = 0.648). While this is in line with the Model 3 results and the descriptive statistics, it was unexpected given the literature review suggested that development should mostly take place in affluent areas with high property values.

The dummy variables PR_GR (location in the province of Groningen) and PR_SH (location in the province of South Holland), too, had negative effects on adaptive reuse, with the odds being 84% (*OR* = 0.156) and 78% (*OR* = 0.223), respectively, lower when compared to location in Drenthe, Gelderland, Friesland, North Brabant, and Zealand together. These findings are consistent with the Model 3 results and the descriptive statistics.

The dummy variables PR_LI (location in the province of Limburg), PR_NH (location in the province of North Holland), PR_OV (location in the province of Overijssel), and PR_UT (location in the province of Utrecht) showed positive effects on adaptive reuse, with the odds being 218% (*OR* = 3.18), 173% (*OR* = 2.73), 314% (*OR* = 4.135), and 400% (*OR* = 4.997), respectively, higher when compared to location in Drenthe, Gelderland, Friesland, North Brabant, and Zealand together. These findings are quite in line with the Model 3 results and the descriptive statistics.

The below equation is the logit function for Model 4. It returns the log of the odds that a historic industrial building in the sample was adaptively reused. By substituting the parameters of Equation 5.1 in Equation 4.1, the sample probabilities of adaptive reuse can be computed (see Section 4.5.3).

$$\begin{aligned}\ln\left(\frac{P(X)}{1-P(X)}\right) = {} & -0.917 + 0.009\text{AGE} - 2.575\text{STR\_WD} - 2.216\text{WDOA\_NO} - 0.916\text{WDOA\_SM} \\ & + 1.33\text{LSTMON} - 1.596\text{INDZN} + 0.314\text{SAD} + 1.114\text{LOT\_MCOR} - 1.9\text{RR\_THRU} \\ & - 0.084\text{DISHWY} - 0.434\text{STAT} - 1.856\text{PR\_GR} + 1.157\text{PR\_LI} + 1.004\text{PR\_NH} \\ & + 1.419\text{PR\_OV} - 1.499\text{PR\_SH} + 1.609\text{PR\_UT}\end{aligned} \tag{5.1}$$

Table 5.12 shows the independent building and location variables in Model 4 ordered by their standardized beta coefficients. As discussed in Section 4.5, the higher the absolute value of the standardized beta coefficient, the stronger the effect of the corresponding independent variable on the dependent variable. The results in the table indicate that INDZN (site with industrial zoning) had relatively the strongest and negative effect on adaptive reuse. LSTMON (listed monument status) had relatively the second strongest and positive effect on adaptive reuse and SAD (surrounding address density) had the third strongest and also positive effect on adaptive reuse. The effect of AGE (building age) on adaptive reuse was half as strong as that of INDZN, while the effect of PR_LI (location in the province of Limburg) was the weakest.

Table 5.12

Effects of building and location variables on industrial heritage adaptive reuse

Building and location variables	Standardized beta coefficient	Direction
1. INDZN (site with industrial zoning)	-0.795	Negative
2. LSTMON (listed monument status)	0.654	Positive
3. SAD (surrounding address density)	0.539	Positive
4. PR_GR (location in the province of Groningen)	-0.523	Negative
5. STAT (area status score)	-0.522	Negative
6. PR_SH (location in the province of South Holland)	-0.507	Negative
7. WDOA_NO (no window area)	-0.448	Negative
8. STR_WD (wooden structure)	-0.445	Negative
9. WDOA_SM (small window area)	-0.423	Negative
10. PR_OV (location in the province of Overijssel)	0.416	Positive
11. DISHWY (distance to nearest highway ramp)	-0.396	Negative
12. AGE (building age)	0.391	Positive
13. PR_UT (location in the province of Utrecht)	0.388	Positive
14. RD_THRU (fronting a through road)	-0.374	Negative
15. LOT_MCOR (multi-corner lot)	0.326	Positive
16. PR_NH (location in the province of North Holland)	0.324	Positive
17. PR_LI (location in the province of Limburg)	0.271	Positive

5.4 Summary

This chapter reported on the empirical results of the study. Descriptive statistics were used to present the data, while logistic regression was applied to assess the effect of 20 independent building and 29 independent location variables on adaptive reuse. Tests of linearity in the logit, multicollinearity, and outliers were conducted on the data prior to the logistic regression analyses. All continuous variables, except for distance to nearest station, were found to be linearly related to the logit of the dependent variable. Hence, the offending variable was square-transformed to meet the linearity assumption. Correlation tests between the independent variables and an analysis of the standardized residuals revealed no presence of multicollinearity and outliers in the data. A null model and three alternative logistic models were stepwise developed. The second and third models assessed the effect of the building and location variables, respectively. The fourth model assessed the effect of both the building and location variables on adaptive reuse. The improvement in model likelihood over the null model by the alternative models ranged from 20% to 56%, and the correctly classified cases by the alternative models ranged from 70% to 82%. The results of the fourth model showed positive effects of the variables building age, listed monument status, surrounding address density, multi-corner lot, and location in the provinces of Overijssel, Utrecht, North Holland, and Limburg on adaptive reuse. In contrast, no window area, small window area, wooden structure, site with industrial zoning, area status score, distance to highway ramp, fronting a through road, and location in the provinces of Groningen and South Holland showed negative effects on adaptive reuse. Overall, these findings are consistent with the descriptive statistics and literature review, except for the results for building age and area status score, which contradict the literature.

6 Discussion and Conclusions

The study started with the premise that adaptive reuse is an effective strategy to preserve industrial heritage buildings, especially when they are threatened by vacancy, decay, and demolition. Adaptive reuse is the process of converting buildings to other, more efficient, and effective uses such that they can better serve user needs and have a useful extended life (Douglas, 2006). Industrial heritage buildings are of significant importance due to their cultural, historical, and technical values and should, therefore, be preserved for future generations. When reused, they can also reduce negative environmental impacts while conserving energy and natural resources (Bullen & Love, 2010). Like others (Ball, 2002; Latham, 2000; Shipley et al., 2006a), the study proposed that the building and, particularly, the location are two of the most important considerations in adaptive reuse. Developers and investors will only invest in adaptive reuse if they believe they can earn an economic gain (Latham, 2000; McGreal et al., 2000). By choosing the right building in the right location, a successful outcome can be more easily achievable (Dyson et al., 2015). From this point on, two main research questions were formulated: (a) Which building and location attributes are considered in the literature as important factors of industrial heritage adaptive reuse? (b) To what extent do these potential factors empirically affect the adaptive reuse of industrial heritage buildings in the Netherlands? To address these questions, a literature review combined with a retrospective case-control study was conducted. Twenty independent building variables and 29 independent location variables, believed to affect adaptive reuse, were derived from literature, and 518 historic industrial buildings, equally divided into a case group of adaptively reused buildings and a control group of vacant buildings, were observed. Logistic regression analyses were conducted to assess the effects of the independent building and location variables on adaptive reuse.

6.1 Key findings

A null model and three alternative logistic models were successively developed using stepwise selection. The second and third models assessed the effects of the building and location variables, respectively, on adaptive reuse. The fourth model assessed the effects of both the building and location variables. Of the 20 building and 29 location variables tested in the fourth model, five building and 12 location variables reached statistical significance. These are discussed below.

Industrial zoning had the strongest and negative effect on adaptive reuse. This is consistent with the literature review, which implied that sites with industrial zoning can be discouraging to adaptive reuse because the zoning regulations in force will likely prohibit a particular change of use (Tan et al., 2014; Tan et al., 2018; Yap, 2013), and because any change to appropriate zoning for the new use can take a long time, likely affecting project cost and risk (Yap, 2013).

Listed monument status had the second strongest and positive effect on adaptive reuse. This is in line with some of the literature reviewed that implied that listed buildings are attractive for adaptive reuse due to their high architectural and historical values (Bullen & Love, 2010, 2011b) and high marketability and market value (Ball, 1999; Bullen & Love, 2010; Kincaid, 2002). However, the result challenges other parts of the literature review that suggested that listed buildings would be severely limited in the types of uses and degree of change allowed, which would make them less prone to adaptive reuse (Douglas, 2006; Latham, 2000). Perhaps the adaptively reused listed buildings in the sample didn't undergo drastic physical changes, or their new use wasn't so different or inconsistent with the original use as to adversely affect their historical character and function.

Increasing surrounding address density had the third strongest and positive effect on adaptive reuse, meaning that the more urban the location, the higher the likelihood of adaptive reuse. This is consistent with the literature review, which suggested that the population or address density is important to (commercial) development because the higher this density is, the shorter distances to services and facilities are, and the lesser the inconvenience to customers is. This will presumably be reflected in higher sales volumes and profits (Salvaneschi, 2002) and, therefore, in higher rents and property values for developers and investors (Jackson, 2001; Thrall, 2002).

Increasing area status score showed a negative effect on adaptive reuse, meaning that the higher the income and education level in the surrounding area, the lower the likelihood of adaptive reuse. This result is challenging because most of the literature reviewed pointed out that property values in high socioeconomic areas are generally higher, which would encourage development (Jackson, 2001; Li & Brown, 1980; Sivitanidou, 1995). A U.S. study found that historic mills in affluent and highly educated areas were more prone to adaptive reuse (Briggs, 2010). However, other parts of the literature review suggested that the area demographics are of little importance as it is the population density that plays a decisive role (Salvaneschi, 2002). A Canadian study reported that declining neighborhood conditions didn't seem to influence adaptive reuse success (Wilson 2010). The observed projects even turned out to assist in revitalizing surrounding areas in decline.

No window area and small window area, too, showed negative effects on adaptive reuse. This is in line with the literature review, which suggested that buildings with small window areas tend to be difficult to let or sell and, thus, less attractive for adaptive reuse (Kincaid, 2002; Stratton, 2000). Yet, care should be taken when interpreting these results as the observed case numbers for no window area were quite low among the adaptively reused buildings compared to the vacant ones.

Wooden structure, too, had a negative effect on adaptive reuse. This is in line with the literature review, which implied that buildings with light and thin walls offer less thermal mass, moisture regulation, and strength for construction handling, making them less suitable for adaptive reuse, as opposed to buildings with heavy and thick walls (Douet, 2012; Douglas, 2006; Langston et al., 2008). Yet, care should be taken when interpreting this result as the observed case numbers for a wooden structure were quite low among the adaptively reused buildings compared to the vacant ones.

Increasing distance to highway ramp, too, had a negative effect on adaptive reuse. This is in line with the literature review, which suggested that buildings in good accessible locations tend to be higher in demand than those in less accessible locations, and therefore tend to have higher market values (Ellison & Sayce, 2007; Netzell, 2013) and be more attractive for adaptive reuse (Ball, 2002; Stratton, 2000). A British study showed that industrial buildings within eight kilometers of a motorway junction were more often reused than those farther away (Ball, 2002).

Increasing building age showed a positive effect on adaptive reuse. This contradicts the literature review, which suggested that older buildings would be less prone to adaptive reuse due to extensive and costly renovations resulting from structural and fabric problems (Bullen & Love, 2011c; Langston et al., 2008). A British study showed that industrial buildings from the post-war era were more often reused than those from the pre-war era (Ball, 1999, 2002). Perhaps the older buildings in the study at hand didn't require major structural and fabric repairs, or perhaps their charm and character outweighed the effort and cost to adaptively reuse them.

Fronting a through road had a negative effect on adaptive reuse. This is consistent with some of the literature reviewed that implied that the effects of exposure to major roads such as air and noise pollution and traffic congestion can be deterrent to certain types of uses (Li & Brown, 1980; Visser et al., 2008; Wilkinson et al., 2014). However, the result contradicts other parts of the literature review that pointed out that it is exactly the exposure from the passing traffic on higher-class roads, which would lead to higher sales volumes and profits (Salvaneschi, 2002) and, therefore, to higher rents and property values for developers and investors (Jackson, 2001; Thrall, 2002).

A multi-corner lot showed a positive effect on adaptive reuse. This is in line with the literature review, which implied that corner lots offer high visibility (Salvaneschi, 2002), making them attractive locations for commercial development (Buckner, 1998; Salvaneschi, 2002; Schiller, 2001).

Location in the provinces of Groningen and South Holland both had a negative effect on adaptive reuse, as opposed to location in the provinces of Limburg, North Holland, Overijssel, and Utrecht, which had positive effects. The effect of location in Limburg was the weakest of all effects in the model. There could be many reasons for these results. Differences in the proportions between the observed number of adaptive reuse and vacancy cases were most likely of influence.

Based on the literature review, the study also produced a summarized table of common types of historic industrial buildings in the Netherlands such as factories, warehouses, and water towers including their typical building and location attributes.

6.2 Recommendations

Based on the literature review and empirical results, several recommendations are provided to developers and investors, local governments, and heritage advocates to facilitate the adaptive reuse of industrial heritage buildings in the Netherlands.

6.2.1 Developers and investors

Developers and investors with a passion for historic buildings are paramount to the heritage development industry. As successive governments have pulled back from direct involvement in development initiatives over the last decades, market and private actors are left to fill the gap. The adaptive reuse of heritage buildings can be a challenging and complex process that requires a passion for the old, a sense of creativity, and the ability to see the opportunity where others do not. Developers and investors considering these types of developments should realize that heritage adaptive reuse is, before anything, about protecting and preserving cultural and historical assets for the present and future to come. At the same time, heritage adaptive reuse developments should be able to generate acceptable returns for developers and investors to participate. As each adaptive reuse project is unique, there is no magic formula that guarantees profitable results. Nevertheless, by selecting the right building in the right location, developers and investors can improve their odds of success. Therefore, developers and investors engaging in the adaptive reuse of industrial heritage buildings should consider the following:

1. Be careful when taking on buildings on sites that still have their original industrial zoning. The respective zoning regulations in force will likely prohibit a particular change of use, making adaptive reuse projects difficult to achieve. This is strongly supported by the empirical results. While a zoning change can be requested, a change to an appropriate zoning required for the intended use is not always possible and if so, can take a long time and, consequently, increase project cost and risk. In addition, possible site contamination will need to be addressed before approval of the rezoning. This will further increase project expenses and reduce profitability.
2. Consider buildings with listed monument status. Listed buildings have high architectural and historical significance, which accounts for their market value and marketability. Therefore, higher returns and shorter absorption periods can be expected, compared to newly built properties. This makes the adaptive reuse of listed industrial heritage buildings an attractive undertaking, despite the restrictions of heritage listing. The empirical results strongly support this reasoning.
3. Consider buildings in highly urban areas. In areas of high density, distances to shops and facilities are shorter than in areas of low density, resulting in less inconvenience for customers. This will presumably be reflected in higher sales volumes and profits and, therefore, in higher rents and property values.
4. Avoid buildings without window areas or with small window areas and buildings with wooden structures. The former tend to be difficult to sell or let, increasing absorption time, while the latter will offer little strength for construction handling and, thus, be difficult to adapt. Although technically, window areas can be made larger and wooden structures be reinforced, these interventions are not always possible due to heritage listing restrictions and standards of architectural quality. Also, such adaptations will substantially increase project cost and duration.
5. Consider buildings located within easy access to highways. Buildings with good access to traffic links are highly desired and sought after, which will presumably be reflected in higher rents and property values. However, being close to major roads and highways will result in considerable

inconvenience in the form of air and noise pollution and traffic congestion, which can be a deterrent to some uses and even cause rents and property values to fall.

6. Consider buildings at multi-corner locations as they enjoy high visibility and exposure, which will presumably be reflected in higher rents and property values.

6.2.2 Local governments

Local governments have an important role in protecting and sustaining heritage assets within their boundaries, irrespective of ownership. As the literature review revealed, adaptive reuse is an effective strategy to preserve historic buildings, particularly those of an industrial nature that have outlived their original use and are at risk of decay or demolition. The social, environmental, and economic benefits that this practice can offer are evident. For that reason, local governments should adopt coherent policies that support adaptive reuse as an integral part of their planning strategies. Therefore, they should consider the following actions:

1. Make an inventory of all (industrial) heritage buildings within the jurisdiction and assess the ones that are vacant and underutilized for adaptive reuse potential. In this regard, potential buildings in socioeconomically deprived areas should also be considered in an effort to revitalize those areas. The techniques and findings presented in this thesis can assist in this process.
2. Inform building owners, developers, and investors about candidate buildings for adaptive reuse. By providing financial incentives, such as grants, interest-free loans, and tax breaks, and regulatory incentives, such as discounted land or long-term tenancy in exchange for developing rights of heritage buildings, the private actors will be encouraged to invest in adaptive reuse. Alternative mechanisms such as public-private partnerships or other forms of multi-stakeholder alliances should also be considered for the purpose of leveraging resources and expertise.
3. Update zoning ordinances and building codes to better accommodate the reuse of vacant industrial buildings and sites. If left to developers to appeal for a zoning change, the petitions can take long and consequently increase project cost and risk. By proactively rezoning vacant industrial sites (delayed cost recoup) to new land uses that better fit within the context, developers and investors will be further incentivized. And by enforcing performance-based building regulations instead of prescriptive-based, designers will have more flexibility to implement necessary adaptations without compromising the heritage values of the buildings.

6.2.3 Heritage advocates

Heritage advocates play an important role in conservation initiatives, especially when demolition threats are looming. They should definitely continue with their efforts to protect and promote heritage buildings in the Netherlands. They should, however, also acknowledge that to safeguard these monuments for the future and bring them into productive use, they need their allies in the development world to make those transformations happen. Heritage developers may not always see and value what the buildings used to look like, as heritage advocates do, but they do see and value what the buildings might look like in the future. Hence, heritage preservation and development don't have to be mutually exclusive. Heritage advocates should, therefore, more often find and support developers that also have a passion for historic buildings and are willing to find a new use for them, bring to bear their development skills on them, and spent money on them.

6.3 Study limitations

The study is subject to some limitations. First, no causal inferences can be made based on the data due to the retrospective nature of the study. The retrospective nature of the study might have also introduced confounding bias. The conducted logistic regression analyses helped address this limitation by controlling for a rich set of building and location variables believed to affect industrial heritage adaptive reuse. It should however be noted that some building and location attributes (building condition, building contamination, ceiling height, building accessibility, building layout, building aesthetics, on-site parking, and site contamination) had to be excluded due to a lack of data. Another limitation is that there was no way to filter the length of the vacancy period due to a lack of data on this aspect. Consequently, the control group included vacant buildings with various lengths of vacancy period. Especially structural vacant buildings (i.e., buildings that have been vacant for more than 3 years without any prospect of future occupancy) are troublesome (Keeris, 2007) and would have alone made better control candidates. A further limitation is that the study relied in part on maps and images provided by web map services such as Google Maps and Planviewer. Because these maps and images were not always clear and up to date, there is no claim of 100 percent accuracy. Finally, the sample might not have been representative of the population due to the non-probability sampling used. To minimize this limitation, sample buildings were selected from sources with national and regional coverage. In addition, buildings selected from these sources were not discarded without reasonable justification, meaning that all industrial heritage buildings listed in these sources had an equal chance of being selected. The sample's representativeness might have also been affected by the possible different proportion of the sample compared to the population. Consequently, the predicted probabilities of adaptive reuse may not coincide with the real probabilities. For the reasons mentioned above, some caution is needed when generalizing the study results, especially concerning the predicted probabilities.

6.4 Future research

Future research should permit the extension and refinement of the inventory of industrial heritage buildings in the Netherlands. This will provide a better insight into the population of these buildings and allow for a better assessment of their adaptive reuse potential. Future work should also be specifically targeted at individual types of historic industrial buildings to better capture the underlying factors at play. The study controlled for six building types and building group types. Initial building types with low frequencies were combined where appropriate. Future research should also involve the building and location attributes that were excluded from further analysis. Moreover, future work should consider factors of particular adaptive reuse outcomes (e.g., retail, office, and residential) instead of adaptive reuse in general. Different outcomes are likely to be affected by different (building and location) factors. Last, future research should further explore the economics of heritage adaptive reuse. The literature review revealed that empirical work on this topic is lacking.

For the real estate sector, it is important to have better insight into the cost and profit of adaptive reuse to make sound investment decisions.

Despite the clear focus of the study on the Netherlands, the topic of heritage adaptive reuse is by no means limited to this country alone. Industry has played a significant role in the industrialization and urbanization of the Western world. The decline of the manufacturing industry since the 1960s has left many historic industrial sites in Western countries abandoned and in disrepair. The data collection techniques and analyses used in the study at hand can therefore be implemented to inventory and assess industrial heritage sites in other places to determine their potential for adaptive reuse as well. As research evolves, more insight will be gained into other factors at play in adaptive reuse, allowing for more advanced strategies to take root.

References

Agresti, A. (2007). *An introduction to categorical data analysis* (2nd ed.). Hoboken, NJ: John Wiley & Sons.

Alfrey, J., & Putnam, T. (1992). *The industrial heritage: Managing resources and uses*. London: Routledge.

Allison, P.D. (2014). Measures of fit for logistic regression. Paper presented at the *SAS Global Forum*. Retrieved from https://support.sas.com/resources/papers/proceedings14/1485-2014.pdf

Architectenbureau J. van Stigt. (2018). Former De Zwijger warehouse in Amsterdam [Photograph]. Retrieved from https://burovanstigt.nl/product/pakhuis-de-zwijger-2/

Austin, R.L., & Woodcock, D.G. (1988). *Adaptive reuse: Issues and case studies in building preservation*. New York, NY: Van Nostrand Reinhold.

Babbie, E. (2010). *The practice of social research* (12th ed.). Belmont, CA: Wadsworth Cengage Learning.

Ball, R.M. (1999). Developers, regeneration and sustainability issues in the reuse of vacant industrial buildings. *Building Research & Information, 27*, 140-148.

Ball, R.M. (2002). Re use potential and vacant industrial premises: Revisiting the regeneration issue in Stoke-on-Trent. *Journal of Property Research, 19*, 93–110.

Bonke, H. (2011). *Amsterdamse pakhuizen: 16de-20ste eeuw*. Zutphen: Walburg Pers.

Box, G.E.P., & Tidwell, P.W. (1962). Transformation of the independent variables. *Technometrics, 4*, 531-550.

Briggs, J.M. (2010). *Locational aspects of adaptive reuse: The case of North Carolina's textile mills* (Master's thesis). Retrieved from https://thescholarship.ecu.edu/handle/10342/2883

Buchanan, R.A. (1989). History and heritage: The development of industrial archaeology in Britain. *The Public Historian, 11*(1), 5-16.

Buckner, R.W. (1998). *Site selection: New advancements in methods and technology*. New York, NY: Lebhar-Friedman Books.

Bullen, P.A., & Love, P.E.D. (2010). The rhetoric of adaptive reuse or reality of demolition: Views from the field. *Cities, 27*, 215-224.

Bullen, P.A., & Love, P.E.D. (2011a). Adaptive reuse of heritage buildings. *Structural Survey, 29*, 411-421.

Bullen, P.A., & Love, P.E.D. (2011b). Factors influencing the adaptive re-use of buildings. *Journal of Engineering, Design and Technology, 9*, 32-46.

Bullen, P.A., & Love, P.E.D. (2011c) A new future for the past: A model for adaptive reuse decision-making. *Built Environment Project and Asset Management, 1*, 32-44.

Cambell, M.J., Julious, S.A., & Altman, D.G. (1995). Estimating sample sizes for binary, ordered categorical, and continuous outcomes in two group comparisons. *BMJ, 311*, 1145-1148.

Christensen, R. (1997). *Log-Linear Models and Logistic Regression* (2nd ed.). New York, NY: Springer.

City of Lakewood, Colorado. (2021). *Subdivision Ordinance of the City of Lakewood, Colorado*. Retrieved from https://www.lakewood.org/Government/Departments/Planning/Subdivision-Ordinance/

Cossons, N. (2012). Why preserve the industrial heritage? In J. Douet (Ed.), Industrial heritage re-tooled: The TICCIH guide to industrial heritage conservation (pp. 6-16). Lancaster: Carnegie.

Creswell, J.W., & Creswell, J.D. (2018). *Research design: Quantitative, qualitative, and mixed methods approaches* (5th ed.). Los Angeles, CA: Sage.

Crompton, J.L. (2005). The impact of parks on property values: Empirical evidence from the past two decades in the United States. *Managing Leisure*, *10*, 203–218.

Cureton, E.E. (1956). Rank-biserial correlation. *Psychometrika, 21,* 287-290.

Cyrenne, P., Fenton, R., & Warbanski, J. (2006). Historic buildings and rehabilitation expenditures: A panel data approach. *Journal of Real Estate Research, 28*, 349-379.

De Koning, J.P. (1996). C. Mommers & Co. woolen factory in Tilburg [Photograph]. Retrieved from https://beeldbank.cultureelerfgoed.nl

De Roeck, F. (2016). Iron foundry at the Piushaven in Tilburg [Photograph]. Retrieved from https://mijnpiushaven.nl/bouw-ijzergieterij-elf-maanden-later/

Dekkers, G., & Wiersma, H. (Eds.). (1986). *Oude fabrieks- en bedrijfsgebouwen in Overijssel*. Zwolle: Waanders.

Dijkstra, L., & Poelman, H. (2012). *Cities in Europe: The new OECD-EC definition* (Paper No. RF 01/2012). Retrieved from European Commission, Directorate-General for Regional and Urban Policy website: https://ec.europa.eu/regional_policy/en/information/publications/

DiPasquale, D., & Wheaton, W.C. (1996). *Urban economics and real estate markets*. Englewood Cliffs, N.J.: Prentice-Hall.

Dorp, Stad en Land. (2016). The Old Map of the Netherlands [Data file].

Douet, J. (Ed.). (2012). *Industrial heritage re-tooled: The TICCIH guide to industrial heritage conservation*. Lancaster: Carnegie.

Douglas, J. (2006). *Building adaptation* (2nd ed.). Oxford, England: Elsevier.

Dreyfus, G. (2005). *Neural networks: Methodology and applications*. Berlin, Germany: Springer.

Duffy, F. (1993). Measuring building performance. *Facilities, 8*, 17-20.

Dunse, N., & Jones, C. (1998). A hedonic price model of office rents. *Journal of Property Valuation & Investment, 16*, 297-312.

Dyson, K., Matthews, J., & Love, P.E.D. (2015). Critical success factors of adapting heritage buildings: An exploratory study. *Built Environment Project and Asset Management, 6*, 44-57.

Ellison, L., & Sayce, S. (2007). Assessing sustainability in the existing commercial property stock. *Property Management, 25*, 287-304.

Espey, M., & Owusu-Edusei, K. (2001). Neighborhood parks and residential property values in Greenville, South Carolina. *Journal of Agricultural and Applied Economics*, *33*, 487-492.

Feilden, B.M. (2003). *Conservation of historic buildings* (3rd ed.). Amsterdam: Architectural Press.

Fraenkel, J.R., Wallen, N.E., & Hyun, H.H. (2012). *How to design and evaluate research in education* (8th ed.). New York, NY: McGraw-Hill.

Fragner, B. (2012). Adaptive re-use. In J. Douet (Ed.), Industrial heritage re-tooled: The TICCIH guide to industrial heritage conservation (pp. 110-117). Lancaster: Carnegie.

Gann, D.M., & Barlow, J. (1996). Flexibility in building use: The technical feasibility of converting redundant offices into flats. *Construction Management & Economics, 14*, 55-66.

Geraedts, R., & Van der Voordt, T. (2003) Offices for living in: An instrument for measuring the potential for transforming offices into homes. *Open House International*, *28*(3): 80-90.

Goossens, N. (2006). *Industrieel erfgoed - tijdelijk definiëren: Een beslissingsondersteunend model Tijdelijke verhuur industrieel erfgoed (BTI-model) voor de ontwikkelaar* (Master's thesis). Retrieved from https://research.tue.nl/en/studentTheses /industrieel-erfgoed-tijdelijkheid-definiëren/

Harmsen, H. (2008). *De oude kaart van Nederland: Leegstand en herbestemming*. The Hague, Netherlands: Atelier Rijksbouwmeester.

Harrison, R. (2013). *Heritage: Critical approaches*. New York, NY: Routledge.

Heins, IJ. (2002). Interior of the former Herman Driessen steam weaving mill in Aalten [Photograph]. Retrieved from https://beeldbank.cultureelerfgoed.nl/

Hemmert, G.A.J., Schons, L.M., Wieseke, J., & Schimmelpfennig, H. (2018). Log-likelihood-based pseudo-R2 in logistic regression: Deriving sample-sensitive benchmarks. *Sociological Methods & Research, 47*, 507-531.

Hewison, R. (1989). Heritage: An interpretation. In D.L. Uzzell (Ed.), *Heritage interpretation: The natural and built environment* (pp. 15-23). London: Belhaven.

Highfield, D. (2000). *Refurbishment and upgrading of buildings*. London, England: E & FN Spon.

Hosmer, D.W., Jr., Lemeshow, S., & Sturdivant, R.X. (2013). *Applied Logistic Regression* (3rd ed.). Hoboken, NJ: John Wiley & Sons.

The International Committee for the Conservation of the Industrial Heritage. (2003). *The Nizhny Tagil Charter for the Industrial Heritage*. Retrieved from http://ticcih.org/about /charter/

Ijla, A.M. (2008). *The impact of local historic designation on residential property values: An analysis of three slow-growth and three fast-growth central cities in the United States* (Doctoral dissertation). Retrieved from http://engagedscholarship.csuohio.edu /etdarchive/139/

Jackson, C. (2001). A model of spatial patterns across local retail property markets in Great Britain. *Urban Studies, 38*, 1445–1471.

Janssen, M. (2013). Van Nelle Factory, Rotterdam [Photograph]. Retrieved from http://www.jkfoto.nl/architectuur-rotterdam/

Kaufman, R.L. (1996). Comparing effects in dichotomous logistic regression: A variety of standardized coefficients. *Social Science Quarterly, 77*, 90-109.

Keeris, W. (2007). Gelaagdheid in leegstand. In T. van der Voordt (Ed.), *Transformatie van kantoorgebouwen: Thema's, actoren, instrumenten en projecten* (pp. 204-2011). Rotterdam: Uitgeverij 010.

Kincaid, D. (2002). *Adapting buildings for changing uses: Guidelines for change of use refurbishment*. London, England: Spon Press.

Kleinbaum, D.G., & Klein, M. (2010). *Logistic regression: A self-learning text* (3rd ed.). New York, NY: Springer.

Kohler, N., & Yang, W. (2007). Long-term management of building stocks. *Building Research and Information, 35*, 351-62.

Kumar, S. (2018). *Predictive analytics for controlling tax evasion* (Master's thesis). Retrieved from https://raiith.iith.ac.in/4218

Kurul, E. (2007). A qualitative approach to exploring adaptive re-use processes. *Facilities, 25*, 554-570.

Langston, C., Wong, F.K.W., Hui, E.C.M., & Shen, L.-Y. (2008). Strategic assessment of building adaptive reuse opportunities in Hong Kong. *Building and Environment, 43*, 1709–1718.

Latham, D. (2000). *Creative re-use of buildings*. Shaftesbury: Donhead.

Lazrak, F., Nijkamp, P., Rietveld, P., & Rouwendal, J. (2014). The market value of cultural heritage in urban areas: An application of spatial hedonic pricing. *Journal of Geographical Systems, 16*, 89-114.

Li, M.M., & Brown, H.J. (1980). Micro-neighborhood externalities and hedonic housing prices. *Land Economics, 56*, 125-141.

Loeff, K. & Beerens, A. (2013). *Industrieel erfgoed: Van buitenbeentje binnen de monumentenzorg naar boegbeeld van de erfgoedzorg*. Leiden: Primavera Pers.

Long, J.S. (1987). A graphical method for the interpretation of multinomial logit analysis. *Sociological Methods and Research, 15*, 420-446.

Loures, L. (2008). Industrial Heritage: The past in the future of the city. *WSEAS Transactions on Environment and Development, 4*, 687-696.

Loures, L. (2015). Post-industrial landscapes as drivers for urban redevelopment: Public versus expert perspectives towards the benefits and barriers of the reuse of post-industrial sites in urban areas. *Habitat International, 45*, 72-81.

Lutzenhiser, M., & Netusil, N.R. (2001). The effect of open spaces on a home's sale price. *Contemporary Economic Policy*, *19*, 291-298.

Martin, P.E. (2009). Industrial archaeology. In T. Majewski & D. Gaimster (Eds.), *International handbook of historical archaeology* (pp. 285-297). New York, NY: Springer.

Mason, R. (2005). *Economics and historic preservation: A guide and review of the literature* (Discussion Paper). Retrieved from Brookings Institution, Metropolitan Policy Program website https://www.brookings.edu/wp-content/uploads/2016/06/20050926_preservation.pdf

McCann, P. (2001). *Urban and regional economics*. Oxford: Oxford University Press.

McGreal, S., Adair, A., Berry, J., Deddis, B., & Hirst, S. (2000). Accessing private sector finance in urban regeneration: Investor and non-investor perspectives. *Journal of Property Research, 17*, 109-131.

McNamee, R. (2005). Regression modelling and other methods to control confounding. *Occupational and Environmental Medicine, 62*, 500–506.

Narwold, A., Sandy, J., & Tu, C. (2008). Historic designation and residential property values. *International Real Estate Review, 11*, 83-95.

Netherlands Institute for Social Research. (2017). Sociaal-Economische Status per postcodegebied (20170912) [Data file]. Retrieved from http://www.scp.nl/Formulieren /Statusscores_opvragen

Netzell, O. (2013). The effect of accessibility on retail rents: Testing integration value as a measure of geographic location. *Journal of Property Research, 30*, 1-23.

Nijhof, P. (1985). *Oude fabrieksgebouwen in Nederland*. Amsterdam, Netherlands: De Bataafsche Leeuw.

Nijhof, P. (1996). *101 industriële monumenten*. Zwolle, Netherlands: Waanders.

Nijhof, P., & Schulte, E. (1994). *Herbestemming industrieel erfgoed in Nederland*. Zutphen, Netherlands: Walburg Pers.

Nijhof, E., & Beernink, G. (1996). *Industrieel erfgoed: Nederlandse monumenten van industrie en techniek*. Utrecht, Netherlands: Teleac.

Nijpels, E.H.T.M. (1995). Hergebruik van industriële gebouwen, een kwestie van smaak. In H.P.G. de Boer (Ed.), *Oude fabrieken, nieuwe functies: Herbestemming industrieel erfgoed* (pp. 6-7). Zeist, Netherlands: Projectbureau Industrieel Erfgoed.

NLExtract. (2017). Key Registers for Addresses and Buildings [Data file 171210]. Retrieved from https://data.nlextract.nl/bag 2017_12_10

Oevermann, H., & Mieg, H.A. (Eds.). (2014). *Industrial heritage sites in transformation: Clash of discourses*. New York, NY: Routledge.

Orford, S. (2002). Valuing locational externalities: A GIS and multilevel modelling approach. *Environment and Planning B: Planning and Design, 29*, 105-127.

Osborne, J.W. (2015). *Best practices in logistic regression*. Los Angeles, CA: SAGE.

Porta, M.S., Greenland, S., Hernán, M., dos Santos Silva, I., & Last, J.M. (Eds.). (2014). *A dictionary of epidemiology* (6th ed.). Oxford: Oxford University Press.

Peca, P. S. (2009). *Real estate development and investment: A comprehensive approach*. Hoboken, NJ: John Wiley & Sons.

Peduzi, P., Concato, J., Kemper, E., Holford, T.R., & Feinstein, A.R. (1996). A simulation study of the number of events per variable in logistic regression analysis. *Journal of Clinical Epidemiology, 49*, 1373-1379.

Rabianski, J.S., Gibler, K.M., Clements, J.S., & Tidwell, O.A. (2009). Mixed-used development and financial feasibility: Part II - Physical, phasing, design and public policy factors. *Real Estate Issues, 34(*2), 17-21.

Reiling, M. (2011). D.F. Wouda Steam Pumping Station, Lemmer [Photograph]. Retrieved from http://www.urbanplan.nl/series/woudagemaal.htm

Reyers, J., & Mansfield, J. (2001). The assessment of risks in conservation refurbishment projects. *Structural Survey, 19*, 238-244.

Rokach, L., & Maimon, O. (2015). *Data mining with decision trees: Theory and applications* (2nd ed.). Singapore: World Scientific Publishing.

Rouwendal, J., Levkovich, O., & Van Marwijk, R. (2017). Estimating the value of proximity to water, when ceteris really is paribus. *Real Estate Economics, 45*, 829-860.

Salkind, N.J. (Ed.). (2010). *Encyclopedia of research design*. Thousand Oaks, CA: SAGE.

Salvaneschi, L. (2002). *Location, location, location: How to select the best site for your business*. Central Point, OR: Oasis Press.

Schalmo, B.E. (2008). *Covering the cost of historic preservation in affordable housing: Exploring the adequacy of the historic rehabilitation tax credit to cover the increased development cost of adaptive reuse projects for affordable housing* (Master's thesis). Retrieved from https://cdr.lib.unc.edu/concern/masters_papers/4t64gp863

Schiller, R. (2001). *The dynamics of property location*. London: Spon Press.

Shadish, W.R., Cook, T.D., & Campbell, D.T. (2002). *Experimental and quasi-experimental designs for generalized causal inference* (2nd ed.). Belmont, CA: Wadsworth Cengage Learning.

Shipley, R., Utz, S., & Parsons, M. (2006a). Does adaptive reuse pay? A study of the business of building renovation in Ontario, Canada. *International Journal of Heritage Studies, 12,* 505-520.

Shipley, R., Utz, S., & Parsons, M. (2006b). *The Lazarus effect: An exploration of the economics of heritage development in Ontario*. Retrieved from University of Waterloo, Heritage Resource Center website: https://uwaterloo.ca/heritage-resources-centre/sites /ca.heritage-resources-centre/files/uploads/files/lazarus-jan20-verA_0.pdf

Sigsworth, E.M., & Wilkinson, R.K. (1967). Rebuilding or renovation? *Urban Studies, 4*, 109-121.

Simonoff, J.S. (2003). *Analyzing categorical data*. New York, NY: Springer.

Sivitanidou, R. (1995). Urban spatial variations in office-commercial rents: The role of spatial amenities and commercial zoning. *Journal of Urban Economics, 38*, 23-49.

Sprinthall, R.C. (2014). *Basic statistical analysis* (9th ed.) Harlow: Pearson.

Stas, N. (2007). *The economics of adaptive reuse of old buildings: A financial feasibility study & analysis* (Master's thesis). Retrieved from: https://uwspace.uwaterloo.ca/handle/10012/2707

Statistics Netherlands. (2017). Kerncijfers wijken en buurten 2017 [Data file]. Retrieved from https://www.cbs.nl/nl-nl/maatwerk/2017/31/kerncijfers-wijken-en-buurten-2017

Stratton, M. (Ed.). (2000). *Industrial buildings: Conservation and regeneration.* London: E & FN Spon.

Suddards, R.W., & Hargreaves, J.M. (1996). *Listed buildings: The law and practice of historic buildings, ancient monuments, and conservation areas*. London: Sweet & Maxwell.

Swallow, P. (1997). Managing unoccupied buildings and sites. *Structural Survey, 15*, 74-79.

Tabachnick, B.G., & Fidell, S.L. (2014). *Using multivariate statistics* (6th ed.). Boston: Pearson.

Tan, Y., Shen, L.-Y., & Langston, C. (2014). A fuzzy approach for adaptive reuse selection of industrial buildings in Hong Kong. *International Journal of Strategic Property Management, 18*, 66-76.

Tan, Y., Shuai, C., & Wang, T. (2018). Critical success factors (CSFs) for the adaptive reuse of industrial buildings in Hong Kong. *International Journal of Environmental Research and Public Health, 15*(7).

Ten Hallers, F. (1987). Protection and special features of the industrial heritage: Experience and deficiencies in several European countries. In Council of Europe, *The industrial heritage: What policies?* (pp. 74-81). Strasbourg: Council of Europe.

Trall, G.I. (2002). *Business geography and new real estate market analysis*. Oxford: Oxford University Press.

Tunbridge, J.E., & Ashworth, G.J. (1996). *Dissonant heritage: The management of the past as a resource in conflict*. Chichester: John Wiley & Sons.

Van Dam, B.B. (2010). Former warehouses at Brouwersgracht in Amsterdam [Photograph]. Retrieved from https://hollandinpixels.photoshelter.com/image/I0000C0r7G38zwds

Van der Veen, H. (1989). *Watertorens in Nederland*. Rotterdam: Uitgeverij 010.

Van der Veen, H. (1994). *Watertorens in Nederland: Waardebepaling en selectie*. Zeist: Stichting Projectbureau Industrieel Erfgoed.

Van Leeuwen, M. (2012, February 29). Industrieel erfgoed maakt inspirerende werkomgeving. *Vastgoedmarkt*, p. 66.

Van Onna, N. (2006). The White Lady in Eindhoven [Photograph]. Retrieved from https://www.herbestemming.nu/projecten/de-witte-dame-eindhoven

Van Zegveld, J. (2012). Former water tower at the Wantij, Dordrecht [Photograph]. Retrieved from http://www.watertorensnederland.nl/watertorens/dordrecht_wantij/dordrecht_wantij.html

Van Zegveld, J. (2013). Former Belcrum water tower in Breda [Photograph]. Retrieved from http://www.watertorensnederland.nl/watertorens/breda_speelhuislaan/breda_speelhuislaan.html

Verbeek, M. (2015). Former water tower in Groningen. [Photograph]. Retrieved from https://en.wikipedia.org/wiki/User:Michielverbeek/Fotoalbum-Groningen

Visser, P., Van Dam, F., & Hooijmeijer, P. (2008). Residential environment and spatial variation in house prices in the Netherlands. *Journal of Economic and Social Geography, 99*, 348-360.

Vittinghoff, E., & McCulloch, C.E. (2006). Relaxing the rule of ten events per variable in logistic and cox regression. *American Journal of Epidemiology, 165*, 710-718.

Warner, R.M., Groff, S.M., & Warner, R.P. (1980). *New profits from old buildings: Private enterprise approaches to making preservation pay*. New York, NY: McGraw-Hill.

Wilkinson, S.J. (2014). The preliminary assessment of adaptation potential in existing office buildings. *International Journal of Strategic Property Management, 18*, 77-87.

Wilkinson, S.J., Remøy, H., & Langston, C. (2014). *Sustainable building adaptation: Innovations in decision-making*. Oxford: Wiley.

Williamson, K. (2010). *Development and design of heritage sensitive sites: Strategies for listed buildings and conservation areas.* London: Routledge.

Wilson, C.A. (2010). *Adaptive reuse of industrial buildings in Toronto, Ontario: Evaluating criteria for determining building selection* (Master's thesis). Retrieved from http://hdl.handle.net/1974/5540

Wong, S.K., Cheung, A.K.C., Yau, Y., Chau, K.W., & Ho, D.C.W. (2005). Distinguishing the decrepit from the old: Is building age a good proxy of building performance? In Y.K. Cheung, & K.W. Chau (Eds.), *Tall buildings: From engineering to sustainability* (pp. 687-692). Singapore: World Scientific.

Yap, K.K. (2013). Industrial building: Exploring its potential in adaptive reuse in Hong Kong. *Proceedings of the International Conference on Construction and Real Estate Management 2013*, 45–58.

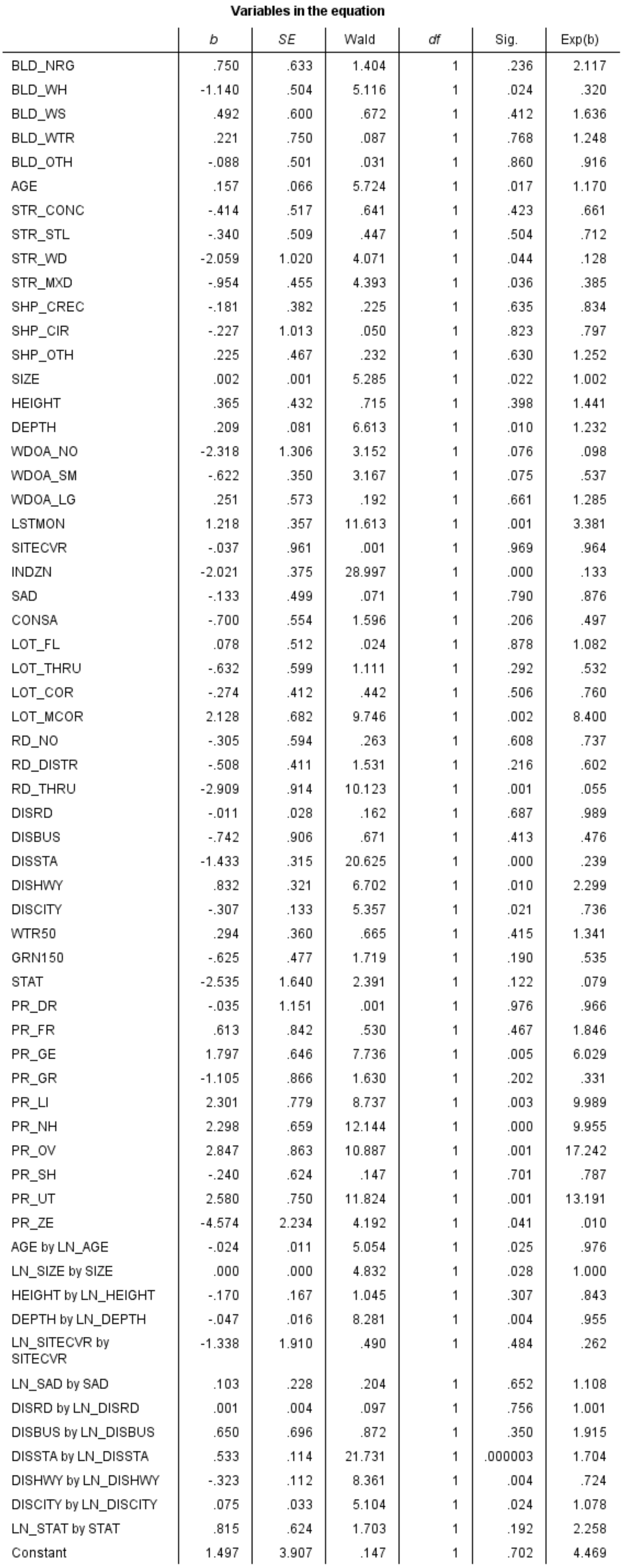
Yau, Y. (2008). Building conditions in Yau Tsim Mong, Hong Kong: Appraisal, exploration and estimation. *Journal of Building Appraisal, 3*, 319-329.

Yuen, B. (2006). Reclaiming cultural heritage in Singapore. *Urban Affairs Review, 41*, 830-854.

Yung, E.H.K., & Chan, E.H.W. (2012). Implementation challenges to the adaptive reuse of heritage buildings: Towards the goals of sustainable, low carbon cities. *Habitat International, 36*, 352-361.

Appendices

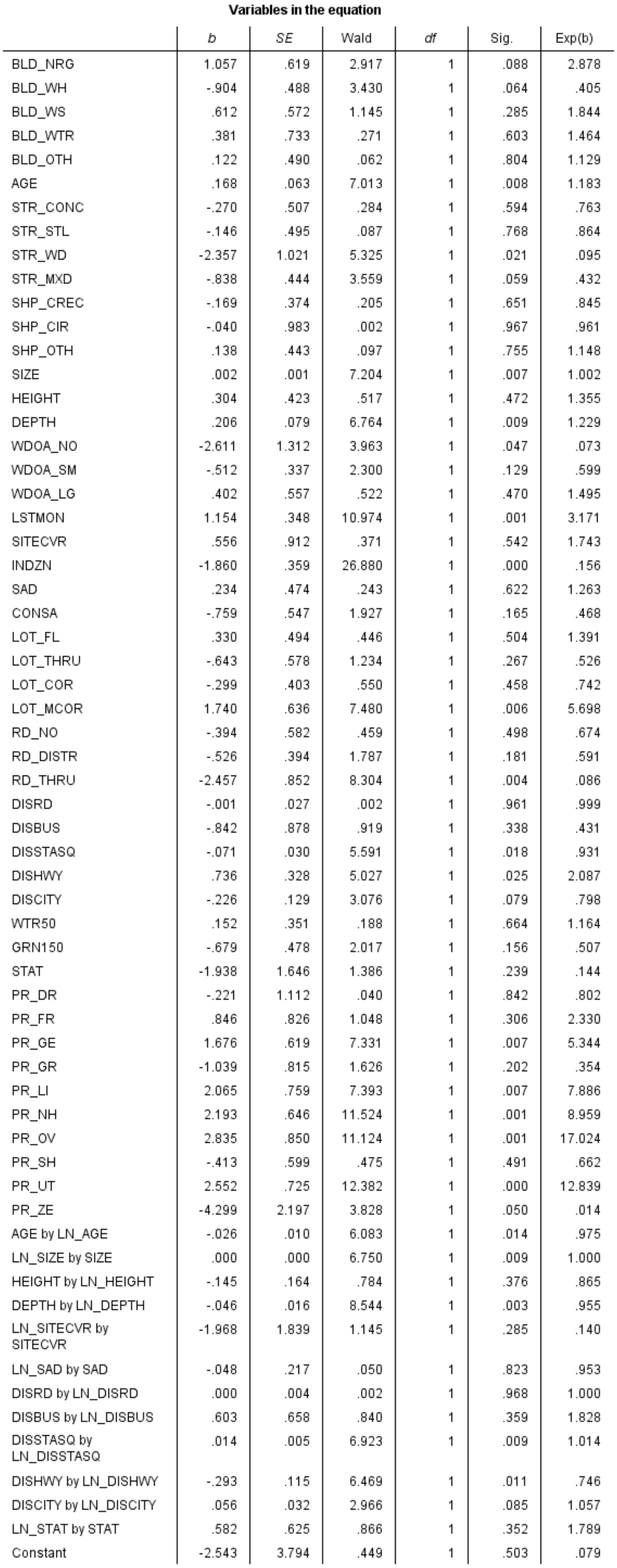
Appendix A: Box-Tidwell test 1 results



Variables in the equation

	b	*SE*	Wald	*df*	Sig.	Exp(b)
BLD_NRG	.750	.633	1.404	1	.236	2.117
BLD_WH	-1.140	.504	5.116	1	.024	.320
BLD_WS	.492	.600	.672	1	.412	1.636
BLD_WTR	.221	.750	.087	1	.768	1.248
BLD_OTH	-.088	.501	.031	1	.860	.916
AGE	.157	.066	5.724	1	.017	1.170
STR_CONC	-.414	.517	.641	1	.423	.661
STR_STL	-.340	.509	.447	1	.504	.712
STR_WD	-2.059	1.020	4.071	1	.044	.128
STR_MXD	-.954	.455	4.393	1	.036	.385
SHP_CREC	-.181	.382	.225	1	.635	.834
SHP_CIR	-.227	1.013	.050	1	.823	.797
SHP_OTH	.225	.467	.232	1	.630	1.252
SIZE	.002	.001	5.285	1	.022	1.002
HEIGHT	.365	.432	.715	1	.398	1.441
DEPTH	.209	.081	6.613	1	.010	1.232
WDOA_NO	-2.318	1.306	3.152	1	.076	.098
WDOA_SM	-.622	.350	3.167	1	.075	.537
WDOA_LG	.251	.573	.192	1	.661	1.285
LSTMON	1.218	.357	11.613	1	.001	3.381
SITECVR	-.037	.961	.001	1	.969	.964
INDZN	-2.021	.375	28.997	1	.000	.133
SAD	-.133	.499	.071	1	.790	.876
CONSA	-.700	.554	1.596	1	.206	.497
LOT_FL	.078	.512	.024	1	.878	1.082
LOT_THRU	-.632	.599	1.111	1	.292	.532
LOT_COR	-.274	.412	.442	1	.506	.760
LOT_MCOR	2.128	.682	9.746	1	.002	8.400
RD_NO	-.305	.594	.263	1	.608	.737
RD_DISTR	-.508	.411	1.531	1	.216	.602
RD_THRU	-2.909	.914	10.123	1	.001	.055
DISRD	-.011	.028	.162	1	.687	.989
DISBUS	-.742	.906	.671	1	.413	.476
DISSTA	-1.433	.315	20.625	1	.000	.239
DISHWY	.832	.321	6.702	1	.010	2.299
DISCITY	-.307	.133	5.357	1	.021	.736
WTR50	.294	.360	.665	1	.415	1.341
GRN150	-.625	.477	1.719	1	.190	.535
STAT	-2.535	1.640	2.391	1	.122	.079
PR_DR	-.035	1.151	.001	1	.976	.966
PR_FR	.613	.842	.530	1	.467	1.846
PR_GE	1.797	.646	7.736	1	.005	6.029
PR_GR	-1.105	.866	1.630	1	.202	.331
PR_LI	2.301	.779	8.737	1	.003	9.989
PR_NH	2.298	.659	12.144	1	.000	9.955
PR_OV	2.847	.863	10.887	1	.001	17.242
PR_SH	-.240	.624	.147	1	.701	.787
PR_UT	2.580	.750	11.824	1	.001	13.191
PR_ZE	-4.574	2.234	4.192	1	.041	.010
AGE by LN_AGE	-.024	.011	5.054	1	.025	.976
LN_SIZE by SIZE	.000	.000	4.832	1	.028	1.000
HEIGHT by LN_HEIGHT	-.170	.167	1.045	1	.307	.843
DEPTH by LN_DEPTH	-.047	.016	8.281	1	.004	.955
LN_SITECVR by SITECVR	-1.338	1.910	.490	1	.484	.262
LN_SAD by SAD	.103	.228	.204	1	.652	1.108
DISRD by LN_DISRD	.001	.004	.097	1	.756	1.001
DISBUS by LN_DISBUS	.650	.696	.872	1	.350	1.915
DISSTA by LN_DISSTA	.533	.114	21.731	1	.000003	1.704
DISHWY by LN_DISHWY	-.323	.112	8.361	1	.004	.724
DISCITY by LN_DISCITY	.075	.033	5.104	1	.024	1.078
LN_STAT by STAT	.815	.624	1.703	1	.192	2.258
Constant	1.497	3.907	.147	1	.702	4.469

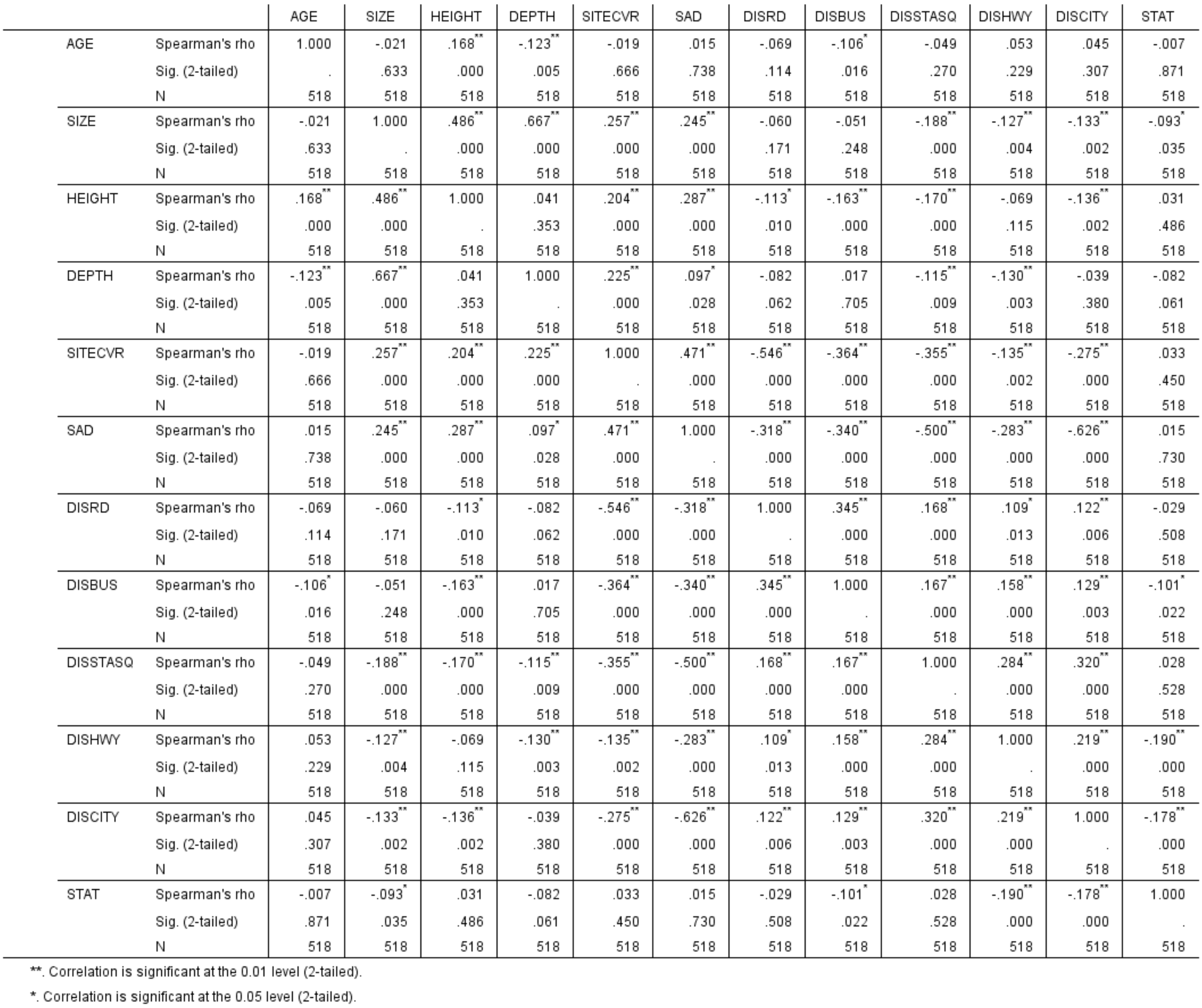
Appendix B: Box-Tidwell test 2 results



Variables in the equation

	b	*SE*	Wald	*df*	Sig.	Exp(b)
BLD_NRG	1.057	.619	2.917	1	.088	2.878
BLD_WH	-.904	.488	3.430	1	.064	.405
BLD_WS	.612	.572	1.145	1	.285	1.844
BLD_WTR	.381	.733	.271	1	.603	1.464
BLD_OTH	.122	.490	.062	1	.804	1.129
AGE	.168	.063	7.013	1	.008	1.183
STR_CONC	-.270	.507	.284	1	.594	.763
STR_STL	-.146	.495	.087	1	.768	.864
STR_WD	-2.357	1.021	5.325	1	.021	.095
STR_MXD	-.838	.444	3.559	1	.059	.432
SHP_CREC	-.169	.374	.205	1	.651	.845
SHP_CIR	-.040	.983	.002	1	.967	.961
SHP_OTH	.138	.443	.097	1	.755	1.148
SIZE	.002	.001	7.204	1	.007	1.002
HEIGHT	.304	.423	.517	1	.472	1.355
DEPTH	.206	.079	6.764	1	.009	1.229
WDOA_NO	-2.611	1.312	3.963	1	.047	.073
WDOA_SM	-.512	.337	2.300	1	.129	.599
WDOA_LG	.402	.557	.522	1	.470	1.495
LSTMON	1.154	.348	10.974	1	.001	3.171
SITECVR	.556	.912	.371	1	.542	1.743
INDZN	-1.860	.359	26.880	1	.000	.156
SAD	.234	.474	.243	1	.622	1.263
CONSA	-.759	.547	1.927	1	.165	.468
LOT_FL	.330	.494	.446	1	.504	1.391
LOT_THRU	-.643	.578	1.234	1	.267	.526
LOT_COR	-.299	.403	.550	1	.458	.742
LOT_MCOR	1.740	.636	7.480	1	.006	5.698
RD_NO	-.394	.582	.459	1	.498	.674
RD_DISTR	-.526	.394	1.787	1	.181	.591
RD_THRU	-2.457	.852	8.304	1	.004	.086
DISRD	-.001	.027	.002	1	.961	.999
DISBUS	-.842	.878	.919	1	.338	.431
DISSTASQ	-.071	.030	5.591	1	.018	.931
DISHWY	.736	.328	5.027	1	.025	2.087
DISCITY	-.226	.129	3.076	1	.079	.798
WTR50	.152	.351	.188	1	.664	1.164
GRN150	-.679	.478	2.017	1	.156	.507
STAT	-1.938	1.646	1.386	1	.239	.144
PR_DR	-.221	1.112	.040	1	.842	.802
PR_FR	.846	.826	1.048	1	.306	2.330
PR_GE	1.676	.619	7.331	1	.007	5.344
PR_GR	-1.039	.815	1.626	1	.202	.354
PR_LI	2.065	.759	7.393	1	.007	7.886
PR_NH	2.193	.646	11.524	1	.001	8.959
PR_OV	2.835	.850	11.124	1	.001	17.024
PR_SH	-.413	.599	.475	1	.491	.662
PR_UT	2.552	.725	12.382	1	.000	12.839
PR_ZE	-4.299	2.197	3.828	1	.050	.014
AGE by LN_AGE	-.026	.010	6.083	1	.014	.975
LN_SIZE by SIZE	.000	.000	6.750	1	.009	1.000
HEIGHT by LN_HEIGHT	-.145	.164	.784	1	.376	.865
DEPTH by LN_DEPTH	-.046	.016	8.544	1	.003	.955
LN_SITECVR by SITECVR	-1.968	1.839	1.145	1	.285	.140
LN_SAD by SAD	-.048	.217	.050	1	.823	.953
DISRD by LN_DISRD	.000	.004	.002	1	.968	1.000
DISBUS by LN_DISBUS	.603	.658	.840	1	.359	1.828
DISSTASQ by LN_DISSTASQ	.014	.005	6.923	1	.009	1.014
DISHWY by LN_DISHWY	-.293	.115	6.469	1	.011	.746
DISCITY by LN_DISCITY	.056	.032	2.966	1	.085	1.057
LN_STAT by STAT	.582	.625	.866	1	.352	1.789
Constant	-2.543	3.794	.449	1	.503	.079

Appendix C: Spearman's correlations



		AGE	SIZE	HEIGHT	DEPTH	SITECVR	SAD	DISRD	DISBUS	DISSTASQ	DISHWY	DISCITY	STAT
AGE	Spearman's rho	1.000	-.021	.168**	-.123**	-.019	.015	-.069	-.106*	-.049	.053	.045	-.007
	Sig. (2-tailed)	.	.633	.000	.005	.666	.738	.114	.016	.270	.229	.307	.871
	N	518	518	518	518	518	518	518	518	518	518	518	518
SIZE	Spearman's rho	-.021	1.000	.486**	.667**	.257**	.245**	-.060	-.051	-.188**	-.127**	-.133**	-.093*
	Sig. (2-tailed)	.633	.	.000	.000	.000	.000	.171	.248	.000	.004	.002	.035
	N	518	518	518	518	518	518	518	518	518	518	518	518
HEIGHT	Spearman's rho	.168**	.486**	1.000	.041	.204**	.287**	-.113*	-.163**	-.170**	-.069	-.136**	.031
	Sig. (2-tailed)	.000	.000	.	.353	.000	.000	.010	.000	.000	.115	.002	.486
	N	518	518	518	518	518	518	518	518	518	518	518	518
DEPTH	Spearman's rho	-.123**	.667**	.041	1.000	.225**	.097*	-.082	.017	-.115**	-.130**	-.039	-.082
	Sig. (2-tailed)	.005	.000	.353	.	.000	.028	.062	.705	.009	.003	.380	.061
	N	518	518	518	518	518	518	518	518	518	518	518	518
SITECVR	Spearman's rho	-.019	.257**	.204**	.225**	1.000	.471**	-.546**	-.364**	-.355**	-.135**	-.275**	.033
	Sig. (2-tailed)	.666	.000	.000	.000	.	.000	.000	.000	.000	.002	.000	.450
	N	518	518	518	518	518	518	518	518	518	518	518	518
SAD	Spearman's rho	.015	.245**	.287**	.097*	.471**	1.000	-.318**	-.340**	-.500**	-.283**	-.626**	.015
	Sig. (2-tailed)	.738	.000	.000	.028	.000	.	.000	.000	.000	.000	.000	.730
	N	518	518	518	518	518	518	518	518	518	518	518	518
DISRD	Spearman's rho	-.069	-.060	-.113*	-.082	-.546**	-.318**	1.000	.345**	.168**	.109*	.122**	-.029
	Sig. (2-tailed)	.114	.171	.010	.062	.000	.000	.	.000	.000	.013	.006	.508
	N	518	518	518	518	518	518	518	518	518	518	518	518
DISBUS	Spearman's rho	-.106*	-.051	-.163**	.017	-.364**	-.340**	.345**	1.000	.167**	.158**	.129**	-.101*
	Sig. (2-tailed)	.016	.248	.000	.705	.000	.000	.000	.	.000	.000	.003	.022
	N	518	518	518	518	518	518	518	518	518	518	518	518
DISSTASQ	Spearman's rho	-.049	-.188**	-.170**	-.115**	-.355**	-.500**	.168**	.167**	1.000	.284**	.320**	.028
	Sig. (2-tailed)	.270	.000	.000	.009	.000	.000	.000	.000	.	.000	.000	.528
	N	518	518	518	518	518	518	518	518	518	518	518	518
DISHWY	Spearman's rho	.053	-.127**	-.069	-.130**	-.135**	-.283**	.109*	.158**	.284**	1.000	.219**	-.190**
	Sig. (2-tailed)	.229	.004	.115	.003	.002	.000	.013	.000	.000	.	.000	.000
	N	518	518	518	518	518	518	518	518	518	518	518	518
DISCITY	Spearman's rho	.045	-.133**	-.136**	-.039	-.275**	-.626**	.122**	.129**	.320**	.219**	1.000	-.178**
	Sig. (2-tailed)	.307	.002	.002	.380	.000	.000	.006	.003	.000	.000	.	.000
	N	518	518	518	518	518	518	518	518	518	518	518	518
STAT	Spearman's rho	-.007	-.093*	.031	-.082	.033	.015	-.029	-.101*	.028	-.190**	-.178**	1.000
	Sig. (2-tailed)	.871	.035	.486	.061	.450	.730	.508	.022	.528	.000	.000	.
	N	518	518	518	518	518	518	518	518	518	518	518	518

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix D: Phi correlations

		BLD_NRG	BLD_WH	BLD_WS	BLD_WTR	BLD_OTH	STR_CONC	STR_STL	STR_WD	STR_MXD	SHP_CREC	SHP_CIR	SHP_OTH	WDOA_NO	WDOA_SM	WDOA_LG	LSTMON	INDZN	CONSA	LOT_FL	LOT_THRU	LOT_COR	LOT_MCOR	RD_NO	RD_DISTR	RD_THRU	WTR50	GRN150	PR_DR	PR_FR	PR_GE	PR_GR	PR_LI	PR_NH	PR_OV	PR_SH	PR_UT	PR_ZE
BLD_NRG	Phi coefficient	1.000	-.157**	-.106*	-.080	-.137**	-.039	-.037	-.058	-.001	.014	.011	-.052	.095*	-.043	-.096*	.053	-.027	-.020	.006	-.070	.091*	-.014	.085	-.055	-.033	-.053	-.023	.098*	.023	.001	.017	.033	-.118**	.008	-.087*	-.001	-.013
	Sig. (2-tailed)	.	.000	.016	.068	.002	.370	.403	.190	.981	.749	.808	.237	.030	.323	.028	.229	.539	.647	.883	.110	.037	.745	.052	.208	.454	.228	.603	.025	.603	.982	.693	.456	.007	.852	.049	.987	.765
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
BLD_WH	Phi coefficient	-.157**	1.000	-.159**	-.121**	-.206**	-.015	.031	.197**	-.086*	-.115**	-.092*	-.065	.190**	.198**	-.130**	-.095*	.034	-.015	-.053	.039	-.085	.044	-.002	-.018	.000	.068	-.051	-.033	.080	-.027	-.010	-.036	-.010	-.023	.131**	-.064	.040
	Sig. (2-tailed)	.000	.	.000	.006	.000	.729	.482	.000	.049	.009	.036	.138	.000	.000	.003	.031	.437	.728	.233	.371	.054	.315	.964	.682	.994	.120	.249	.460	.070	.534	.812	.408	.820	.603	.003	.149	.362
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
BLD_WS	Phi coefficient	-.106*	-.159**	1.000	-.081	-.139**	-.166**	.111*	.017	-.005	-.093*	-.062	.022	-.036	.066	-.016	.020	.007	.021	.067	-.072	-.066	-.016	.098*	-.029	-.067	-.058	-.025	.002	.021	-.126**	.062	-.025	.124**	-.061	-.088*	.079	.066
	Sig. (2-tailed)	.016	.000	.	.065	.002	.000	.011	.696	.917	.033	.159	.621	.408	.134	.714	.643	.879	.628	.131	.104	.131	.711	.025	.512	.127	.189	.568	.970	.629	.004	.161	.569	.005	.166	.044	.072	.131
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
BLD_WTR	Phi coefficient	-.080	-.121**	-.081	1.000	-.105*	-.040	-.034	-.044	-.035	-.075	.585**	-.075	-.011	.122**	-.064	.147**	-.041	.055	.030	-.011	-.007	.005	.053	.061	.075	-.027	.031	.085	-.055	-.019	-.018	-.061	.038	.005	.075	-.029	.010
	Sig. (2-tailed)	.068	.006	.065	.	.017	.361	.436	.315	.425	.090	.000	.089	.799	.006	.146	.001	.347	.214	.490	.795	.872	.917	.225	.165	.089	.542	.484	.052	.214	.660	.686	.162	.393	.917	.088	.506	.827
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
BLD_OTH	Phi coefficient	-.137**	-.206**	-.139**	-.105*	1.000	.132**	-.162**	-.045	-.191**	-.110*	-.022	.034	-.089*	-.108*	-.003	-.015	-.027	.019	.025	-.025	.084	-.082	.007	.031	.076	-.006	.082	-.060	-.042	.061	.003	-.036	.012	-.045	.010	.047	-.038
	Sig. (2-tailed)	.002	.000	.002	.017	.	.003	.000	.310	.000	.012	.620	.441	.042	.014	.954	.741	.534	.664	.570	.571	.056	.062	.872	.475	.083	.900	.061	.176	.335	.165	.953	.411	.792	.303	.820	.283	.393
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
STR_CONC	Phi coefficient	-.039	-.015	-.166**	-.040	.132**	1.000	-.266**	-.099*	-.300**	-.036	-.006	.057	-.049	-.133**	.297**	-.018	-.081	-.034	.029	.107*	-.008	.178**	-.098*	.119**	.047	-.001	.037	-.045	-.101*	-.034	-.058	.038	.009	.054	-.054	-.067	-.036
	Sig. (2-tailed)	.370	.729	.000	.361	.003	.	.000	.024	.000	.413	.893	.198	.264	.002	.000	.685	.065	.440	.511	.015	.857	.000	.025	.007	.282	.982	.401	.309	.022	.435	.187	.392	.839	.222	.219	.129	.408
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
STR_STL	Phi coefficient	-.037	.031	.111*	-.034	-.162**	-.266**	1.000	-.086	-.259**	-.009	-.010	-.033	.120**	.056	.027	-.188**	.113**	.021	-.036	-.031	.036	.014	.015	-.103*	.002	-.116**	-.092*	-.067	-.059	-.023	-.095*	.050	.101*	.014	.004	-.062	.012
	Sig. (2-tailed)	.403	.482	.011	.436	.000	.000	.	.051	.000	.831	.820	.453	.006	.203	.536	.000	.010	.637	.417	.485	.415	.752	.725	.019	.969	.008	.036	.126	.182	.598	.030	.252	.022	.752	.929	.162	.793
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
STR_WD	Phi coefficient	-.058	.197**	.017	-.044	-.045	-.099*	-.086	1.000	-.096*	-.007	-.034	-.006	.128**	.075	-.030	.010	.108*	-.060	-.040	-.011	-.054	-.058	.002	-.105*	.020	.065	.000	.056	.067	-.048	-.015	-.044	.039	-.020	.096*	.001	.039
	Sig. (2-tailed)	.190	.000	.696	.315	.310	.024	.051	.	.028	.880	.442	.887	.003	.089	.499	.816	.014	.175	.369	.803	.222	.190	.966	.016	.652	.142	.995	.203	.129	.273	.726	.315	.380	.657	.029	.990	.375
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
STR_MXD	Phi coefficient	-.001	-.086*	-.005	-.035	-.191**	-.300**	-.259**	-.096*	1.000	.103*	-.052	.120**	-.091*	.021	-.123**	.151**	.031	.004	-.003	.098*	-.094*	-.017	.006	-.013	-.017	.074	.018	-.009	.035	.038	.096*	-.015	-.040	.015	-.046	.034	-.005
	Sig. (2-tailed)	.981	.049	.917	.425	.000	.000	.000	.028	.	.019	.237	.006	.039	.635	.005	.001	.477	.929	.940	.025	.032	.702	.883	.762	.693	.092	.676	.844	.431	.389	.029	.728	.366	.738	.297	.440	.917
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
SHP_CREC	Phi coefficient	.014	-.115**	-.093*	-.075	-.110*	-.036	-.009	-.007	.103*	1.000	-.114**	-.240**	-.040	-.070	-.054	-.049	.043	-.041	.097*	.050	-.029	-.031	.053	-.017	-.013	-.047	.009	.011	.096*	.043	.016	.075	-.098*	-.060	-.053	-.010	-.047
	Sig. (2-tailed)	.749	.009	.033	.090	.012	.413	.831	.880	.019	.	.009	.000	.360	.113	.217	.269	.326	.346	.027	.258	.515	.486	.229	.700	.765	.282	.838	.809	.029	.330	.722	.088	.025	.169	.227	.829	.290
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
SHP_CIR	Phi coefficient	.011	-.092*	-.062	.585**	-.022	-.006	-.010	-.034	-.052	-.114**	1.000	-.076	.012	.171**	-.069	.078	-.108*	.042	.028	.062	.022	-.025	-.008	.056	.068	-.064	.024	.127**	.008	-.055	.016	-.047	.061	.047	-.011	-.005	.033
	Sig. (2-tailed)	.808	.036	.159	.000	.620	.893	.820	.442	.237	.009	.	.086	.780	.000	.119	.077	.014	.342	.519	.162	.615	.565	.852	.200	.123	.147	.592	.004	.850	.212	.711	.285	.162	.288	.797	.911	.448
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
SHP_OTH	Phi coefficient	-.052	-.065	.022	-.075	.034	.057	-.033	-.006	.120**	-.240**	-.076	1.000	-.084	.003	.049	.056	-.123**	.184**	-.114**	-.034	.035	-.014	-.131**	.047	.003	.134**	.086*	.026	-.034	-.038	-.023	-.003	-.006	-.033	.045	-.056	.037
	Sig. (2-tailed)	.237	.138	.621	.089	.441	.198	.453	.887	.006	.000	.086	.	.056	.954	.269	.200	.005	.000	.009	.444	.425	.755	.003	.290	.937	.002	.050	.560	.434	.385	.597	.951	.886	.455	.312	.206	.395
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
WDOA_NO	Phi coefficient	.095*	.190**	-.036	-.011	-.089*	-.049	.120**	.128**	-.091*	-.040	.012	-.084	1.000	-.140**	-.076	-.175**	.117**	.057	-.018	-.062	-.023	-.035	.073	-.037	.054	-.049	-.022	-.030	-.001	.063	-.031	-.052	-.047	-.068	.003	-.054	.024
	Sig. (2-tailed)	.030	.000	.408	.799	.042	.264	.006	.003	.039	.360	.780	.056	.	.001	.083	.000	.007	.195	.689	.161	.606	.422	.095	.401	.222	.265	.618	.502	.984	.151	.482	.235	.283	.122	.943	.219	.587
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
WDOA_SM	Phi coefficient	-.043	.198**	.066	.122**	-.108*	-.133**	.056	.075	.021	-.070	.171**	.003	-.140**	1.000	-.241**	-.060	.055	-.013	.037	-.009	-.025	-.043	.063	.037	-.052	-.003	.013	-.002	.052	.014	.018	-.022	-.009	-.086*	.088*	-.014	.096*
	Sig. (2-tailed)	.323	.000	.134	.006	.014	.002	.203	.089	.635	.113	.000	.954	.001	.	.000	.171	.215	.761	.403	.837	.578	.323	.151	.401	.238	.939	.764	.962	.234	.754	.689	.623	.831	.049	.044	.745	.030
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
WDOA_LG	Phi coefficient	-.096*	-.130**	-.016	-.064	-.003	.297**	.027	-.030	-.123**	-.054	-.069	.049	-.076	-.241**	1.000	.091*	-.133**	-.041	.015	.162**	-.042	.151**	-.094*	.062	.017	-.126**	-.028	-.051	-.080	-.061	-.026	.091*	-.039	.172**	-.087*	-.018	.014
	Sig. (2-tailed)	.028	.003	.714	.146	.954	.000	.536	.499	.005	.217	.119	.269	.083	.000	.	.038	.002	.356	.733	.000	.341	.001	.033	.161	.693	.004	.527	.249	.070	.165	.555	.038	.380	.000	.048	.688	.749
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
LSTMON	Phi coefficient	.053	-.095*	.020	.147**	-.015	-.018	-.188**	.010	.151**	-.049	.078	.056	-.175**	-.060	.091*	1.000	-.263**	.101*	-.056	.018	-.027	.080	-.110*	.118**	-.032	.106*	.005	.083	-.034	.028	-.089*	.012	-.036	-.041	.118**	.031	-.066
	Sig. (2-tailed)	.229	.031	.643	.001	.741	.685	.000	.816	.001	.269	.077	.200	.000	.171	.038	.	.000	.022	.206	.687	.536	.070	.012	.007	.471	.016	.915	.059	.439	.526	.042	.783	.412	.352	.007	.481	.133
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
INDZN	Phi coefficient	-.027	.034	.007	-.041	-.027	-.081	.113**	.108*	.031	.043	-.108*	-.123**	.117**	.055	-.133**	-.263**	1.000	-.108*	.081	-.136**	-.085	-.014	.153**	-.038	-.048	.016	-.038	-.099*	-.107*	-.040	.093*	.025	-.078	-.080	.028	.171**	.136**
	Sig. (2-tailed)	.539	.437	.879	.347	.534	.065	.010	.014	.477	.326	.014	.005	.007	.215	.002	.000	.	.014	.065	.002	.053	.754	.000	.390	.274	.712	.389	.025	.015	.366	.034	.570	.078	.069	.529	.000	.002
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
CONSA	Phi coefficient	-.020	-.015	.021	.055	.019	-.034	.021	-.060	.004	-.041	.042	.184**	.057	-.013	-.041	.101*	-.108*	1.000	-.019	-.050	-.038	-.020	.008	.081	-.036	.223**	.145**	.000	.049	-.147**	-.012	.055	-.002	-.064	.213**	-.086	-.016
	Sig. (2-tailed)	.647	.728	.628	.214	.664	.440	.637	.175	.929	.346	.342	.000	.195	.761	.356	.022	.014	.	.660	.253	.393	.647	.861	.064	.412	.000	.001	.997	.269	.001	.789	.214	.955	.145	.000	.051	.715
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
LOT_FL	Phi coefficient	.006	-.053	.067	.030	.025	.029	-.036	-.040	-.003	.097*	.028	-.114**	-.018	.037	.015	-.056	.081	-.019	1.000	-.154**	-.244**	-.170**	.490**	-.192**	.058	-.031	-.072	.063	-.116**	.100*	.121**	-.070	-.061	-.058	-.107*	.157**	-.001
	Sig. (2-tailed)	.883	.233	.131	.490	.570	.511	.417	.369	.940	.027	.519	.009	.689	.403	.733	.206	.065	.660	.	.000	.000	.000	.000	.000	.184	.478	.104	.155	.008	.023	.006	.112	.166	.191	.015	.000	.986
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
LOT_THRU	Phi coefficient	-.070	.039	-.072	-.011	-.025	.107*	-.031	-.011	.098*	.050	.062	-.034	-.062	-.009	.162**	.018	-.136**	-.050	-.154**	1.000	-.136**	-.095*	-.084	-.010	-.024	-.027	-.068	-.041	.071	.007	-.090*	-.011	.048	.174**	-.029	-.046	-.005
	Sig. (2-tailed)	.110	.371	.104	.795	.571	.015	.485	.803	.025	.258	.162	.444	.161	.837	.000	.687	.002	.253	.000	.	.002	.031	.058	.822	.586	.542	.123	.350	.104	.877	.040	.795	.274	.000	.506	.301	.914
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
LOT_COR	Phi coefficient	.091*	-.085	-.066	-.007	.084	-.008	.036	-.054	-.094*	-.029	.022	.035	-.023	-.025	-.042	-.027	-.085	-.038	-.244**	-.136**	1.000	-.150**	-.181**	.014	.058	-.047	.053	-.028	-.030	-.013	-.054	.015	.018	-.012	-.046	-.014	-.015
	Sig. (2-tailed)	.037	.054	.131	.872	.056	.857	.415	.222	.032	.515	.615	.425	.606	.578	.341	.536	.053	.393	.000	.002	.	.001	.000	.753	.186	.287	.231	.518	.491	.775	.223	.741	.678	.783	.296	.745	.731
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
LOT_MCOR	Phi coefficient	-.014	.044	-.016	.005	-.082	.178**	.014	-.058	-.017	-.031	-.025	-.014	-.035	-.043	.151**	.080	-.014	-.020	-.170**	-.095*	-.150**	1.000	-.102*	.065	-.033	-.053	-.063	.003	-.008	-.089*	-.076	.061	.046	.008	-.067	-.028	-.013
	Sig. (2-tailed)	.745	.315	.711	.917	.062	.000	.752	.190	.702	.486	.565	.755	.422	.323	.001	.070	.754	.647	.000	.031	.001	.	.020	.139	.454	.228	.154	.953	.847	.044	.083	.165	.300	.852	.128	.523	.765
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
RD_NO	Phi coefficient	.085	-.002	.098*	.053	.007	-.098*	.015	.002	.006	.053	-.008	-.131**	.073	.063	-.094*	-.110*	.153**	.008	.490**	-.084	-.181**	-.102*	1.000	-.280**	-.097*	-.150**	-.059	.006	-.033	.076	.137**	-.075	-.111*	-.034	-.096*	.148**	.013
	Sig. (2-tailed)	.052	.964	.025	.225	.872	.025	.725	.966	.883	.229	.852	.003	.095	.151	.033	.012	.000	.861	.000	.058	.000	.020	.	.000	.027	.001	.180	.891	.450	.085	.002	.089	.011	.442	.030	.001	.763
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
RD_DISTR	Phi coefficient	-.055	-.018	-.029	.061	.031	.119**	-.103*	-.105*	-.013	-.017	.056	.047	-.037	.037	.062	.118**	-.038	.081	-.192**	-.010	.014	.065	-.280**	1.000	-.121**	.048	.016	-.019	-.088*	-.080	.100*	.042	-.052	.005	.136**	-.115**	.010
	Sig. (2-tailed)	.208	.682	.512	.165	.475	.007	.019	.016	.762	.700	.200	.290	.401	.401	.161	.007	.390	.064	.000	.822	.753	.139	.000	.	.006	.279	.720	.669	.045	.067	.023	.337	.240	.912	.002	.009	.815
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
RD_THRU	Phi coefficient	-.033	.000	-.067	.075	.076	.047	.002	.020	-.017	-.013	.068	.003	.054	-.052	.017	-.032	-.048	-.036	.058	-.024	.058	-.033	-.097*	-.121**	1.000	-.002	.070	.042	.001	.095*	-.029	-.009	.077	-.033	-.080	-.053	-.034
	Sig. (2-tailed)	.454	.994	.127	.089	.083	.282	.969	.652	.693	.765	.123	.937	.222	.238	.693	.471	.274	.412	.184	.586	.186	.454	.027	.006	.	.961	.112	.337	.977	.030	.515	.837	.081	.454	.069	.231	.437
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
WTR50	Phi coefficient	-.053	.068	-.058	-.027	-.006	-.001	-.116**	.065	.074	-.047	-.064	.134**	-.049	-.003	-.126**	.106*	.016	.223**	-.031	-.027	-.047	-.053	-.150**	.048	-.002	1.000	.214**	.033	.089*	-.080	.079	-.061	.104*	-.094*	.208**	.027	-.034
	Sig. (2-tailed)	.228	.120	.189	.542	.900	.982	.008	.142	.092	.282	.147	.002	.265	.939	.004	.016	.712	.000	.478	.542	.287	.228	.001	.279	.961	.	.000	.456	.042	.069	.072	.167	.018	.033	.000	.538	.435
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
GRN150	Phi coefficient	-.023	-.051	-.025	.031	.082	.037	-.092*	.000	.018	.009	.024	.086*	-.022	.013	-.028	.005	-.038	.145**	-.072	-.068	.053	-.063	-.059	.016	.070	.214**	1.000	-.053	-.083	-.040	-.013	-.019	-.048	.117**	.163**	.121**	-.027
	Sig. (2-tailed)	.603	.249	.568	.484	.061	.401	.036	.995	.676	.838	.592	.050	.618	.764	.527	.915	.389	.001	.104	.123	.231	.154	.180	.720	.112	.000	.	.227	.058	.362	.761	.665	.276	.008	.000	.006	.537
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_DR	Phi coefficient	.098*	-.033	.002	.085	-.060	-.045	-.067	.056	-.009	.011	.127**	.026	-.030	-.002	-.051	.083	-.099*	.000	.063	-.041	-.028	.003	.006	-.019	.042	.033	-.053	1.000	-.031	-.062	-.043	-.035	-.051	-.045	-.055	-.036	-.023
	Sig. (2-tailed)	.025	.460	.970	.052	.176	.309	.126	.203	.844	.809	.004	.560	.502	.962	.249	.059	.025	.997	.155	.350	.518	.953	.891	.669	.337	.456	.227	.	.482	.161	.326	.429	.244	.303	.215	.414	.595
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_FR	Phi coefficient	.023	.080	.021	-.055	-.042	-.101*	-.059	.067	.035	.096*	.008	-.034	-.001	.052	-.080	-.034	-.107*	.049	-.116**	.071	-.030	-.008	-.033	-.088*	.001	.089*	-.083	-.031	1.000	-.097*	-.068	-.055	-.081	-.071	-.086	-.057	-.037
	Sig. (2-tailed)	.603	.070	.629	.214	.335	.022	.182	.129	.431	.029	.850	.434	.984	.234	.070	.439	.015	.269	.008	.104	.491	.847	.450	.045	.977	.042	.058	.482	.	.027	.122	.214	.067	.105	.051	.199	.404
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_GE	Phi coefficient	.001	-.027	-.126**	-.019	.061	-.034	-.023	-.048	.038	.043	-.055	-.038	.063	.014	-.061	.028	-.040	-.147**	.100*	.007	-.013	-.089*	.076	-.080	.095*	-.080	-.040	-.062	-.097*	1.000	-.136**	-.109*	-.161**	-.142**	-.171**	-.113*	-.073
	Sig. (2-tailed)	.982	.534	.004	.660	.165	.435	.598	.273	.389	.330	.212	.385	.151	.754	.165	.526	.366	.001	.023	.877	.775	.044	.085	.067	.030	.069	.362	.161	.027	.	.002	.013	.000	.001	.000	.010	.096
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_GR	Phi coefficient	.017	-.010	.062	-.018	.003	-.058	-.095*	-.015	.096*	.016	.016	-.023	-.031	.018	-.026	-.089*	.093*	-.012	.121**	-.090*	-.054	-.076	.137**	.100*	-.029	.079	-.013	-.043	-.068	-.136**	1.000	-.076	-.113*	-.100*	-.120**	-.079	-.051
	Sig. (2-tailed)	.693	.812	.161	.686	.953	.187	.030	.726	.029	.722	.711	.597	.482	.689	.555	.042	.034	.789	.006	.040	.223	.083	.002	.023	.515	.072	.761	.326	.122	.002	.	.082	.010	.023	.006	.072	.243
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_LI	Phi coefficient	.033	-.036	-.025	-.061	-.036	.038	.050	-.044	-.015	.075	-.047	-.003	-.052	-.022	.091*	.012	.025	.055	-.070	-.011	.015	.061	-.075	.042	-.009	-.061	-.019	-.035	-.055	-.109*	-.076	1.000	-.091*	-.080	-.096*	-.064	-.041
	Sig. (2-tailed)	.456	.408	.569	.162	.411	.392	.252	.315	.728	.088	.285	.951	.235	.623	.038	.783	.570	.214	.112	.795	.741	.165	.089	.337	.837	.167	.665	.429	.214	.013	.082	.	.039	.068	.028	.148	.348
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_NH	Phi coefficient	-.118**	-.010	.124**	.038	.012	.009	.101*	.039	-.040	-.098*	.061	-.006	-.047	-.009	-.039	-.036	-.078	-.002	-.061	.048	.018	.046	-.111*	-.052	.077	.104*	-.048	-.051	-.081	-.161**	-.113*	-.091*	1.000	-.118**	-.142**	-.094*	-.061
	Sig. (2-tailed)	.007	.820	.005	.393	.792	.839	.022	.380	.366	.025	.162	.886	.283	.831	.380	.412	.078	.955	.166	.274	.678	.300	.011	.240	.081	.018	.276	.244	.067	.000	.010	.039	.	.007	.001	.033	.166
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_OV	Phi coefficient	.008	-.023	-.061	.005	-.045	.054	.014	-.020	.015	-.060	.047	-.033	-.068	-.086*	.172**	-.041	-.080	-.064	-.058	.174**	-.012	.008	-.034	.005	-.033	-.094*	.117**	-.045	-.071	-.142**	-.100*	-.080	-.118**	1.000	-.126**	-.083	-.054
	Sig. (2-tailed)	.852	.603	.166	.917	.303	.222	.752	.657	.738	.169	.288	.455	.122	.049	.000	.352	.069	.145	.191	.000	.783	.852	.442	.912	.454	.033	.008	.303	.105	.001	.023	.068	.007	.	.004	.059	.221
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_SH	Phi coefficient	-.087*	.131**	-.088*	.075	.010	-.054	.004	.096*	-.046	-.053	-.011	.045	.003	.088*	-.087*	.118**	.028	.213**	-.107*	-.029	-.046	-.067	-.096*	.136**	-.080	.208**	.163**	-.055	-.086	-.171**	-.120**	-.096*	-.142**	-.126**	1.000	-.100*	-.065
	Sig. (2-tailed)	.049	.003	.044	.088	.820	.219	.929	.029	.297	.227	.797	.312	.943	.044	.048	.007	.529	.000	.015	.506	.296	.128	.030	.002	.069	.000	.000	.215	.051	.000	.006	.028	.001	.004	.	.023	.141
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_UT	Phi coefficient	-.001	-.064	.079	-.029	.047	-.067	-.062	.001	.034	-.010	-.005	-.056	-.054	-.014	-.018	.031	.171**	-.086	.157**	-.046	-.014	-.028	.148**	-.115**	-.053	.027	.121**	-.036	-.057	-.113*	-.079	-.064	-.094*	-.083	-.100*	1.000	-.043
	Sig. (2-tailed)	.987	.149	.072	.506	.283	.129	.162	.990	.440	.829	.911	.206	.219	.745	.688	.481	.000	.051	.000	.301	.745	.523	.001	.009	.231	.538	.006	.414	.199	.010	.072	.148	.033	.059	.023	.	.331
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
PR_ZE	Phi coefficient	-.013	.040	.066	.010	-.038	-.036	.012	.039	-.005	-.047	.033	.037	.024	.096*	.014	-.066	.136**	-.016	-.001	-.005	-.015	-.013	.013	.010	-.034	-.034	-.027	-.023	-.037	-.073	-.051	-.041	-.061	-.054	-.065	-.043	1.000
	Sig. (2-tailed)	.765	.362	.131	.827	.393	.408	.793	.375	.917	.290	.448	.395	.587	.030	.749	.133	.002	.715	.986	.914	.731	.765	.763	.815	.437	.435	.537	.595	.404	.096	.243	.348	.166	.221	.141	.331	.
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix E: Rank-biserial correlations

		BLD_NRG	BLD_WH	BLD_WS	BLD_WTR	BLD_OTH	STR_CONC	STR_STL	STR_WD	STR_MXD	SHP_CREC	SHP_CIR	SHP_OTH	WDOA_NO	WDOA_SM	WDOA_LG	LSTMON	INDZN	CONSA	LOT_FL	LOT_THRU	LOT_COR	LOT_MCOR	RD_NO	RD_DISTR	RD_THRU	WTR50	GRN150	PR_DR	PR_FR	PR_GE	PR_GR	PR_LI	PR_NH	PR_OV	PR_SH	PR_UT	PR_ZE
AGE	Rank-biserial coefficient	.035	-.074	.031	.080	-.089	-.231	-.235	.070	.150	-.020	.097	.099	-.060	-.081	-.104	.327	-.300	.175	-.027	-.008	-.010	-.136	-.026	.035	.064	.207	.027	.110	.118	.003	.081	-.087	.062	-.041	.044	-.068	-.035
	Sig. (2-tailed)	.432	.092	.477	.070	.044	.000	.000	.111	.001	.642	.028	.025	.173	.067	.017	.000	.000	.000	.542	.858	.814	.002	.550	.433	.149	.000	.540	.013	.007	.953	.065	.048	.156	.352	.314	.120	.428
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
SIZE	Rank-biserial coefficient	-.122	-.117	-.067	-.137	-.252	.282	.085	-.133	.261	.237	-.110	.115	-.151	-.169	.249	.170	-.066	.029	-.013	.170	-.052	.194	-.153	.008	-.014	-.013	-.005	-.065	-.100	-.028	-.149	.101	.094	.027	-.051	-.033	-.012
	Sig. (2-tailed)	.006	.007	.129	.002	.000	.000	.052	.002	.000	.000	.012	.009	.001	.000	.000	.000	.133	.508	.775	.000	.234	.000	.000	.849	.756	.767	.905	.140	.022	.532	.001	.022	.033	.539	.249	.449	.791
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
HEIGHT	Rank-biserial coefficient	-.044	-.114	-.195	.142	-.010	.339	-.207	-.145	.103	.030	.253	.082	-.177	-.143	.216	.278	-.303	.150	-.062	.163	-.013	.096	-.201	.090	.017	.050	.011	.054	-.029	-.047	-.072	-.013	.074	.048	.053	-.085	-.070
	Sig. (2-tailed)	.318	.009	.000	.001	.827	.000	.000	.001	.019	.489	.000	.061	.000	.001	.000	.000	.000	.001	.158	.000	.776	.029	.000	.040	.706	.257	.803	.218	.510	.281	.102	.762	.093	.273	.227	.052	.113
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
DEPTH	Rank-biserial coefficient	-.088	.009	.010	-.230	-.357	.009	.238	-.001	.254	.270	-.177	.103	-.062	-.012	.041	.002	.085	-.041	-.019	.126	-.075	.104	-.088	-.076	-.073	-.038	-.061	-.048	.000	-.057	-.119	.111	.049	.019	-.013	.000	.048
	Sig. (2-tailed)	.045	.835	.824	.000	.000	.831	.000	.980	.000	.000	.000	.019	.160	.792	.353	.956	.053	.351	.665	.004	.087	.018	.046	.082	.098	.386	.167	.277	.994	.195	.007	.012	.267	.674	.762	.999	.278
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
SITECVR	Rank-biserial coefficient	-.107	.101	-.038	-.139	-.055	.143	.057	-.018	-.011	-.026	-.194	.181	-.048	-.010	.085	.114	-.266	.157	-.255	.033	.058	.170	-.300	-.055	-.041	.110	.102	-.025	.038	-.127	-.182	-.005	.178	.000	.120	-.072	-.052
	Sig. (2-tailed)	.015	.021	.394	.002	.214	.001	.195	.688	.810	.556	.000	.000	.275	.814	.054	.009	.000	.000	.000	.451	.187	.000	.000	.212	.351	.012	.020	.574	.387	.004	.000	.909	.000	1.000	.006	.102	.233
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
SAD	Rank-biserial coefficient	-.015	-.066	-.042	-.077	.029	.223	.005	.012	-.080	-.098	-.054	.182	-.086	-.090	.147	.178	-.285	.224	-.257	.086	.150	.159	-.240	.051	-.100	.078	.138	-.105	-.112	-.191	-.229	.056	.155	-.012	.187	.061	-.114
	Sig. (2-tailed)	.732	.136	.345	.081	.516	.000	.904	.785	.070	.026	.217	.000	.050	.041	.001	.000	.000	.000	.000	.050	.001	.000	.000	.250	.022	.077	.002	.017	.011	.000	.000	.204	.000	.790	.000	.163	.009
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
DISRD	Rank-biserial coefficient	.105	-.077	.001	.125	.031	.015	.027	-.032	-.046	.104	.131	-.204	.076	.032	.019	-.118	.190	-.145	.514	-.062	-.130	-.157	.565	.037	.087	-.144	-.098	.061	-.102	.076	.123	-.017	-.110	.001	-.078	.073	.031
	Sig. (2-tailed)	.017	.082	.983	.004	.477	.736	.546	.472	.301	.018	.003	.000	.085	.470	.666	.007	.000	.001	.000	.157	.003	.000	.000	.397	.047	.001	.026	.168	.021	.085	.005	.705	.012	.975	.076	.097	.477
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
DISBUS	Rank-biserial coefficient	.046	-.034	-.083	-.001	-.039	-.008	.041	-.021	-.001	.121	-.004	-.153	.029	.035	-.039	-.137	.272	-.152	.322	-.087	-.143	-.031	.276	-.164	-.095	.050	-.111	.007	.071	.121	.042	.013	-.129	-.028	-.170	.090	.026
	Sig. (2-tailed)	.295	.437	.060	.977	.372	.848	.349	.627	.982	.006	.929	.000	.513	.426	.377	.002	.000	.001	.000	.047	.001	.479	.000	.000	.030	.260	.012	.881	.106	.006	.339	.768	.003	.520	.000	.040	.558
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
DISSTASQ	Rank-biserial coefficient	-.036	-.005	.022	.049	.023	-.102	-.004	.022	.002	.033	-.024	-.064	.094	.013	-.180	-.069	.247	.007	.094	-.106	-.069	-.089	.163	.067	.002	.074	-.050	.083	.017	.008	.122	-.025	-.108	-.019	.030	-.128	.090
	Sig. (2-tailed)	.411	.904	.622	.271	.605	.021	.927	.614	.959	.456	.585	.148	.032	.771	.000	.116	.000	.878	.033	.016	.115	.043	.000	.126	.973	.092	.255	.059	.697	.853	.006	.575	.014	.667	.499	.004	.041
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
DISHWY	Rank-biserial coefficient	.106	-.007	.018	.024	-.063	-.051	-.022	.021	-.022	-.001	.042	-.079	.047	.036	.010	-.046	.079	-.003	.029	-.024	-.076	-.033	.211	.101	-.084	-.051	-.108	.022	.067	.128	.213	-.047	-.204	.016	-.151	-.074	.069
	Sig. (2-tailed)	.016	.874	.676	.581	.149	.246	.611	.636	.625	.983	.341	.072	.291	.408	.825	.300	.072	.951	.510	.585	.084	.450	.000	.021	.056	.247	.014	.616	.127	.003	.000	.290	.000	.708	.001	.092	.116
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
DISCITY	Rank-biserial coefficient	.031	-.023	-.005	.013	-.044	-.124	-.039	.048	.104	.054	.079	-.043	.042	.009	.025	-.099	.080	-.190	.064	.044	-.121	-.109	.076	-.099	.084	-.079	-.055	.178	.143	.143	.207	.012	-.113	.227	-.308	-.168	.262
	Sig. (2-tailed)	.486	.604	.910	.776	.319	.005	.372	.271	.017	.221	.071	.331	.339	.833	.575	.024	.070	.000	.148	.322	.006	.013	.082	.024	.056	.072	.208	.000	.001	.001	.000	.788	.010	.000	.000	.000	.000
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518
STAT	Rank-biserial coefficient	-.059	.089	-.044	.080	.032	-.021	-.054	-.014	-.011	-.113	.075	.018	.039	.072	-.052	.035	.035	.139	-.022	-.032	.007	-.095	-.077	.094	.031	.053	.055	-.076	-.195	-.087	-.140	-.002	.144	.077	.222	.011	-.062
	Sig. (2-tailed)	.182	.044	.318	.069	.473	.637	.217	.748	.802	.010	.088	.683	.379	.101	.235	.431	.432	.001	.614	.471	.877	.031	.081	.033	.479	.225	.211	.085	.000	.048	.001	.970	.001	.079	.000	.807	.158
	N	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518	518

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed)