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A COST MODEL TO IMPROVE SHORT-TERM UNDERINSURANCE OF RESIDENTIAL BUILDINGS IN SOUTH AFRICA

by

Elma Inge Pieterse

a thesis submitted in fulfilment of the requirements for the degree

DOCTOR OF PHILOSOPHY (QUANTITY SURVEYING)

Study Leader: Prof JHH Cruywagen

in the Faculty of Engineering, Built Environment and Information Technology
University of Pretoria

March 2024

DECLARATION

I, Elma Inge Pieterse, declare that this research is entirely my own, unaided work, except where otherwise stated. All sources referred to are adequately acknowledged and listed in the text.

I accept the rules of assessment of the University of Pretoria and the consequences of transgressing them.

This thesis is being submitted to fulfil the requirements for the Doctor of Philosophy (Quantity Surveying) degree in the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria.

This thesis has not been submitted before for any degree or examination at any other university.

28.03.2024

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DATE

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ABSTRACT

A cost model to address short-term insurance of residential buildings in South Africa

by

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This thesis demonstrates the development of a case-based reasoning (CBR) enabled cost estimating method for residential buildings in South Africa for application in the insurance environment to address the continuous under-insurance gap perpetuated by inappropriate cost models. The CBR comprises the four steps of retrieving, re-using, revising and retaining cases from the custom-designed dataset. The dataset contains data for forty-five cases based on traditional building elemental estimates and fourteen design features. The elemental estimates are based on the built environment's entrenched measuring methodology, and the features are designed to address shortcomings in the currently applied cost models for determining replacement cost estimates for insurance purposes. Estimates based on

these measuring methods are still regarded as the most accurate predictions of actual cost. The measuring process is laborious, time-consuming, requires specialist-built environment involvement, and is costly. The cost outweighs the perceived risk of insuring for the correct sum. The proposed CBR method addresses all these aspects. The k-nearest neighbour (kNN) machine learning algorithm performs the first step to retrieve the cases from the dataset with features most similar to the case under investigation. The other steps of re-using, revising and retaining are performed through mathematical model-based reasoning. The mathematical estimating model requires the input of fourteen design features extracted from the case under investigation's drawing that are pro-rated to the features of the retrieved nearest neighbours and multiplied by the elemental values to produce replacement cost estimates for the case under investigation. One hundred and thirty-five estimation iterations based on the chosen nearest neighbours were performed. The model shows the promise to provide accurate replacement cost estimates for insurance purposes, as the results obtained show 59% of the iterations to be within 10% accuracy of the elemental estimates. Machine learning techniques are not widely practised in cost modelling in South Africa's built environment. The potential for developing and implementing cost models for various purposes, more than just insurance purposes, is immeasurable and could place the built environment truly on the Fourth Industrial Revolution trajectory.

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LIST OF ACRONYMS

AACE	International Association for the Advancement of Cost Engineering
ABI	Association of British Insurers
ASAQS -	Association of South African Quantity Surveyors
BCIS	Building Cost Information Service
BRICS -	Grouping of Brazil, Russia, India, China and South Africa
CAHF -	Centre for Affordable Housing Finance
CBR -	Case-Based Reasoning
CPA -	Consumer Protection Act
ESG -	Environmental, Social and Governmental
FAISA -	Financial Advisory and Intermediary Services Act
FSB -	Financial Services Board
FSBA	Financial Services Board Act
G7 -	Grouping of United States of America, United Kingdom, Canada, Germany, France, Japan and Italy
GDP -	Gross Domestic Product
GEFA	Gross external floor area
GIFA	Gross internal floor area
IA -	Insurance Act
ICMS -	International Cost Management Standard
IDC -	Industrial Development Corporation
kNN -	K Nearest Neighbour
LTIA -	Long Term Insurance Act
OEDC	Organisation for Economic Development and Co-operation

PPR -	Policyholder Protection Rules
PSCC -	Property Sector Charter Council
PSI -	Principles for Sustainable Insurance
RDP	Reconstruction and Development Programme
RICS -	Royal Institute of Charted Surveyors
SARB -	South African Reserve Bank
SSM7 -	Standard System of Measuring Building Work (7^{th} Edition)
STIA -	Short Term Insurance Act
TCF -	Treating Customers Fairly
UN	United Nations
UNEP FI	United Nations Environment Programme Financial Initiative
UK	United Kingdom
USA	United States of America

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CHAPTER 1: INTRODUCTION, BACKGROUND AND PROBLEM STATEMENTS

1.1 INTRODUCTION

Being or becoming a homeowner has significant benefits such as the creation of personal wealth, greater residential stability and security, better quality housing and living environment, social and physical benefits of interacting in a better neighbourhood and a sense of accomplishment derived from the social status and better control over one's own living conditions (Rohe & Lindblad, 2013). According to McCarthy *et al.* (2001), housing is an excellent financial investment that delivers a decent return and falls between the higher returns of riskier stock market investments and lower returns of less risky bond investments.

Any financial investment is associated with a fair amount of risk. For many individuals, the investment in a home is the most significant in their lives; hence, protecting the assets against any threats is paramount. In a 1958 song by Ollie Jones, Perry Como sings about love that makes the world go around and, in the musical, 'Cabaret' Lisa Minelli sings about money that makes the world go around. Still, according to Longcore (2006), insurance makes the world go around in a modern and sophisticated economic environment.

Exceptionally few people could afford houses, motor cars, or any other assets of substantial value without the assurance that the assets and, thus, their financial interests were protected. Insurance is the recognition and treatment of financial, economic and social risks associated with the financial resilience required to reinstate assets to their state before damage occurs due to some disasters such as fires, storms, floods or earthquakes are thus necessary.

Short-term insurance is the most commonly practised risk treatment method to protect high-value assets. This method entails transferring the risks to a third party through a short-term insurance policy. The basic premise of short-term insurance is thus that the insurers accept future risks in return for the premiums paid towards the insurance policy. Insureds need the assurance that they are sufficiently financially protected by the risk-transfer instruments purchased. Having insufficient or no coverage is financially devastating if a catastrophic loss occurs. Purchasing insurance at a slightly higher rate or even purchasing excessive coverage is unlikely to be as detrimental to an individual's financial situation as no insurance or under-insurance would be (Kunreuther *et al.,* 2013*).*

Inadequate short-term insurance is a reality that short-term insurers constantly caution against, yet the situation prevails. Inadequate short-term building insurance, called under-insurance or a protection gap, is a global phenomenon (Swiss Re Sigma, 2015).

The trauma the insured experiences due to their inability to fully recover from disruptive events that caused substantial physical and financial damage to their property is the reality of under-insurance. The increased frequency of occurrences of unusual inclement weather, fires in densely developed and populated neighbourhoods, electrical surges, and so on, and the severity of the damage caused to buildings, mainly single residential buildings, aggravate the situation. The most vulnerable are individuals at the bottom of the personal wealth chain. In South Africa, post-1994, with economic emancipation high on previously disadvantaged individuals’ priority, protecting newly acquired high-value assets is particularly important.

Determining the insurance value is the responsibility and choice of the insured. Such a choice should be based on knowledge about the probability of any disruptive event occurring and understanding the extent of the probable damage that could happen to their property. In reality, little or no information pertaining to the probability of different perils occurring is available to insureds. Information related to the probable value of the damage, thus the building cost, is equally unavailable in the public domain. The scantly available building cost information is either too simplistic and inaccurate or too complex and expensive to obtain.

Without adequate and reliable building cost information in the South African public domain to assist homeowners in obtaining appropriate property insurance values, individuals turn to readily available sources such as neighbours, friends, colleagues, estate agents, and so on. (Swiss Re Sigma, 2015). The result is that the entire risk intended to be transferred to the insurer is not transferred, and an insurance protection gap develops.

Insurance companies are careful to develop mechanisms to assist insureds in obtaining the appropriate values for residential property insurance because of the contractual responsibility for determining the correct value vests with the insured. However, some South African insurance companies offer basic calculators to determine building costs. The output of these calculators is qualified so that the insurer does not guarantee the output's accuracy and / or completeness and, hence, does not accept any liability for loss or damage that might emanate from the calculator's application. Understandably, insurers would adopt such an approach where the insurer does not have control over the accuracy of the information inserted into such a calculator.

Determining building costs is the expert domain of quantity surveyors. When dealing with the costs of individual building projects, quantity surveyors strive to build comprehensive cost databases for different types of buildings, building elements, and the like to enable them to estimate future developments as accurately as possible. This method is called product-based costing (Seeley, 1996; Kirkham, 2007). The processes for determining product-based costing are well established in quantity surveying practice.

The question then arises as to why the under-insurance of buildings, specifically residential buildings, prevails if it is a known threat. The presumed answer to this question is that insufficient building cost information is available in the public domain to accurately address the insured values. The problem is further compounded by the fact that quantity surveyors are rarely involved in residential property developments. Hence, the methods and techniques developed in practice are more suited to complex commercial, industrial and retail building developments. A critical analysis of the building elements applicable to complex buildings is necessary to determine their applicability to residential buildings.

1.2 ORIGIN OF THE RESEARCH IDEA

The short-term insurance supply chain starts with potential insureds having to choose the appropriate method for procuring an insurance product and to decide on the actual value of insurance. At this early stage, the only involvement from the insurance supply chain is either the telephone operators acting for direct marketers, electronic applications through the World Wide Web or brokers acting on behalf of one of several insurance companies. Little assistance is offered with regard to the appropriate insurance value for the replacement cost of the residential buildings.

However, the terms and conditions of the insurance policies are explained to the potential insureds. A standard clause of particular importance, that of the principle of averages, might be specifically highlighted. However, insureds cannot fully comprehend this clause’s whole meaning or potential impact under circumstances where insureds are unaware that the value insured for is insufficient.

In the event of significant damage to a building, the insurance company deploys a contingent of intermediaries to investigate the damage. These intermediaries include loss adjusters, civil engineers, quantity surveyors, and other necessary intermediaries. What is of particular importance is that the quantity surveyor is to determine the replacement cost as well as the cost of the damage. The replacement cost is used to test the value insured, and if found inadequate, the principle of averages is applied to the value of the claim (cost of damage), resulting in a reduced payment. The replacement cost included in an insurance policy is referred to as the value at risk. When a quantity surveyor determines the replacement cost at the time of claim, the process is referred to as testing the value at risk. If the value at risk is found to be inadequate, the punitive measure, the principle of averages, is applied.

It is thus only at this point that the insured becomes aware of the under-insurance. Apart from the severe disruption to the insured’s lives and having to arrange alternative accommodation while their damaged property is repaired, the insured is also informed of the detrimental financial reality of their claim not being paid in full.

The detrimental situation described above and the possible contribution to the prevention thereof are the drivers behind undertaking this research.

1.3 RESEARCH PROBLEMS, AIMS AND OBJECTIVES

1.3.1 Problem Statements

The context of the problem suggests that the solution to the under-insurance conundrum is a trans-discipline one. The current methods generally applied to determine residential building insurance values are insufficient to inform the correct and accurate insurance values.

These shortcomings call for developing an efficient cost model that focuses explicitly on determining total or partial replacement costs of damaged residential buildings for short-term insurance purposes. The gap between the insurance and quantity surveying disciplines can be breached by combining well-developed quantity surveying techniques, modern statistical models and machine learning techniques.

The cost model needs to be simple enough to be utilised by non-built environment professionals. Yet, it must deliver results accurately and sufficiently to ensure adequate short-term insurance.

The main problem statement and sub-problem statements that arise from the discussion above are set out in Figure 1.1.

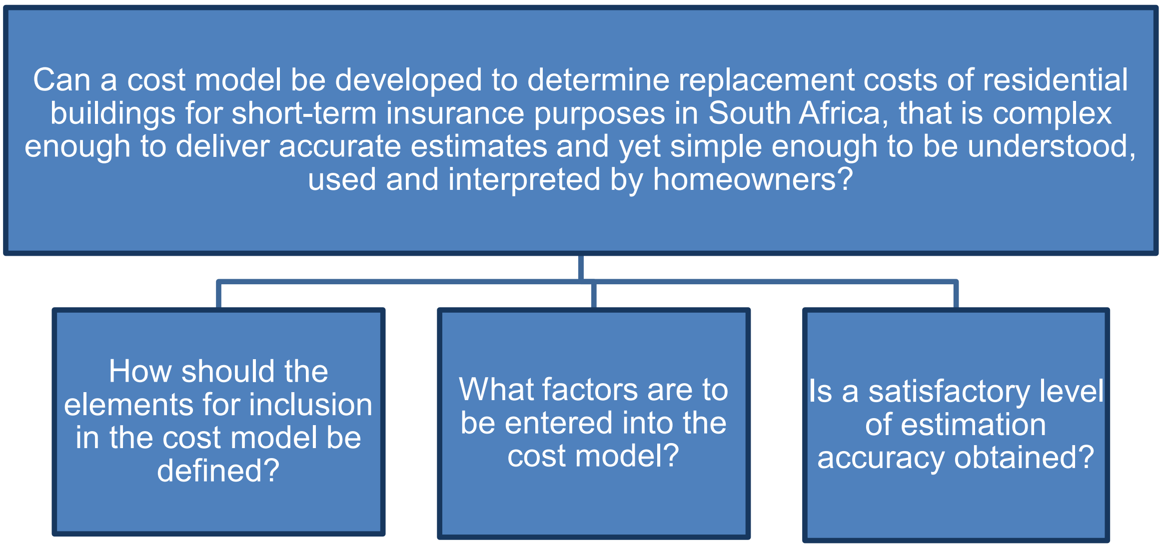

Figure 1.1: Main and Sub-problem Statements
Source: Author's own

1.3.2 The premises

The main problem statement is premised on the possibility of developing a cost model to determine residential building replacement costs for short-term insurance purposes in South Africa. The cost model must be complex enough to deliver accurate estimates yet simple enough to be understood, used and interpreted by homeowners.

The main problem can be solved by addressing the sub-problems first. The first sub-problem is premised on consistently applying the defined building elements for inclusion into the cost model.

The second sub-problem's premise is that the chosen factors to be entered into the cost model accurately address aspects such as fullness on plan, the shape of the building, height of the building and the like, that impact the replacement cost of buildings the most.

The third sub-problem's premise is that a satisfactory level of estimation accuracy is obtained.

1.3.3 Research aim

This research aims to develop a cost model by implementing the case-based reasoning (CBR) methodology that consists of the four stages of retrieving, reusing, revising and retaining cases. The cases in the research are the quantified residential plans. Comparable cases are retrieved from an existing database and evaluated relative to the new case to be estimated. In so doing the chosen case is reused. The selected case is then revised to suit the new case, and the new case is retained by introducing it into the database for future selection if it meets the accuracy criteria. The CBR methodology relies on the processes developed to retrieve and revise the cases of instances. A machine learning technique is employed for the retrieval, and a mathematical formula is devised to perform the revision. The outcome of the CBR method is applied to each case in the database to determine whether significantly improved estimated replacement costs of residential buildings for insurance purposes have been achieved. The data input into the cost model must simultaneously prove to be statistically significant.

The proposed cost model aims to support the reduction of homeowners' financial vulnerability in the event of any damage occurring to the property. In addition to solving the research problem at hand, the cost model could potentially provide a mechanism that could be implemented to facilitate challenges experienced during insurance claims processes.

1.3.4 Research objectives

The research seeks to develop a database consisting of the following:

- sample residential buildings measured according to a standardised system of measuring building quantities.
- formulated building elements relevant to residential buildings.
- measured building quantities arranged according to formulated building elements.

- factors derived from the formulated building elements.

The generation and preparation of the data according to the objectives above serve both the machine learning algorithm applied to retrieve cases from the database and the mathematical model envisaged to determine the reuse, revision and retaining of cases.

1.4 DELIMITATIONS TO THE STUDY

Delimitations or characteristics of the study that are within the control of the researcher are framed as follows:

- Only stand-alone single-storey residential properties in South Africa are included in the study data.
- The houses range in size from 40 square metres to 610 square metres and are based on drawings that could be obtained for this research.
- Some of the drawings used were sourced from national residential property developers, others were sourced from the researcher's private practice, and others were randomly sourced from individual property owners. Sourcing the drawings proved more difficult than initially anticipated, as many home-owners do not have drawings of their property.
- Luxury estate-style dwellings with extraordinary design features are expressly excluded.

- The measured quantities are priced at similar rates to exclude the effect of the time value of money and locational cost fluctuation from the results.

Stand-alone single-storey residential properties dominate the housing typology in South Africa. Although the development of alternative housing types such as sectional title complexes, high-rise apartment developments and the like are increasing, stand-alone single-storey properties remain the preferred option.

The choice of the buildings included in the study is deliberated in Chapter 2 as part of the research methodology.

Luxury estate-style houses are excluded, firstly because they represent only approximately 5% of the housing stock in South Africa and secondly, because their complexity resembles that of a commercial building more than most houses in South Africa.

This study aims to develop a calculator to determine replacement costs for residential buildings. It is a common cause that there will be fluctuations in costs over time and in different locations. To assess only the influence of various design parameters on the cost of buildings, it is necessary to exclude the effect of time and location adjustments on the costs. Should the development of a calculator, as envisaged by this study, prove to be successful, the logical continuation would be to create a cost database premised on real-life cases that would include the time and location influences.

The outcome of this study could, however, generally apply to all stand-alone, single-storey residences in South Africa.

1.5 LIMITATIONS TO THE STUDY

The limitations of this study, which are beyond the control of the researcher, include:

- The limited sample size - Due to the non-involvement of quantity surveyors in the residential market, obtaining data at a scale was impossible. Hence, data had to be generated from base quantity surveying principles specifically for use in this research.
- Non-representativity of the sample – an asserted effort was made to source building plans that are as diverse as possible and would represent residential properties across the economic classes throughout South Africa (except for the luxury dwellings expressly excluded from this research). It is, however, possible that a sample of other combinations could impact the study's outcome.
- Reliability and validity of the measures – firstly, the data is generated by measuring the quantities from the drawings according to the standardised methodology prescribed for use by all quantity surveyors

in South Africa. There is a degree of consistency in applying the measurement rules, as the researcher quantified all the drawings. Had data been available from other sources, there might have been some inconsistency in the quantification. Similarly, the quantification is classified according to a globally prescribed cost reporting format. Also, there could be differing allocations if different individuals were involved in this process.

- Data classification and analysis involve the application of a machine-learning algorithm and a mathematical model to facilitate the steps of the case-based reasoning method. Several algorithms exist. The k-nearest neighbour (kNN) algorithm was selected due to its specific attributes. Various other factors could have been designed and built into the mathematical model.

1.6 ASSUMPTIONS

The dwelling designs used to generate the data for the study are assumed to be applicable and representative of all regions throughout South Africa.

Furthermore, it is assumed that stand-alone dwellings will remain the predominant choice of property.

1.7 EXPECTED CONTRIBUTION AND IMPORTANCE OF THE STUDY

The prevailing under-insurance scenario that has its worst impact on individuals at the bottom of the wealth chain and the possibility that the outcome of this study, the proposed cost model, could contribute to alleviating the situation are the expected contributions of this study.

The cost model developed through this research could inform different stakeholders in the insurance environment, such as insurance brokers, loss adjusters, claims handlers, insurance companies and the like, of more accurate replacement costs and, in the process, reduce the risks faced by all parties involved.

1.8 OUTLINE OF THE STUDY

This research is presented in eight chapters, including the current chapter, which has framed the background and research problems to investigate. The following chapter outline is summarised in the paragraphs below to provide a concise focus of each chapter.

1.8.1 Chapter 2: Research Methodology

The overall research philosophy, including the research design and methodology, including the research instruments, data sampling and collection, data analysis, validity and reliability of the research and the interpretation of the research findings, are outlined in this chapter. The quantitative research approach implemented in developing the proposed cost model is discussed in detail in the appropriate chapters.

Chapters 3, 4 and 5 cover literature reviews that will inform the study's theoretical basis from the point of view of each of the insurance and built environment disciplines and the merged view.

1.8.2 Chapter 3: The Insurance Environment

Although the main problem and sub-problem statements do not directly address aspects of insurance, the study's premise is that a cost model is developed to serve the insurance industry specifically. Thus, this necessitates understanding the insurance industry, its basic principles and the context wherein the problem is identified.

1.8.3 Chapter 4: Linking the insurance industry and the built environment

In this chapter, the global economic impact of the insurance industry's property classes, insurers' perceptions of their risk and the development and influence of third-party data and model providers on the insurance industry are presented to illustrate the interrelationship between the insurance industry and the built environment.

1.8.4 Chapter 5: The Built and Quantity Surveying Cost Environment

Quantity surveyors primarily perform cost modelling in the built environment. The type of cost models and the appropriate associated design stage to which they apply are discussed.

The cost models currently applied in different countries are interrogated and compared to the cost models used in quantity surveying practice.

The empirical section of the research commences from Chapter 6 onwards.

1.8.5 Chapter 6: Generation and Presentation of the Data

The process of generating the raw cost data, defining the elements and converting the raw data into the building elements for input into the dataset is presented. The aspects involved in generating the data and determining the elements are discussed. The necessity and the process of creating a two-stage cost model are demonstrated.

1.8.6 Chapter 7: Analysis of the Data

In this chapter, the actual working of the two-stage cost model and the CBR methodology is demonstrated. The extent to which the study has succeeded in its aim and has addressed the research questions is revealed.

1.8.7 Chapter 8: Summary and Direction for further research

The thesis concludes with a summary of the main findings, and suggestions for further research are provided.

CHAPTER 2: RESEARCH METHODOLOGY

2.1 INTRODUCTION

This chapter outlines the overarching research methodology followed in executing the research. Before engaging in the details of the research methodology, the research philosophy needs to be discussed. Saunders *et al*. (2009) refer to their research onion, starting with the philosophy as the outer layer and moving inwards with the approach, strategy, method choices, techniques and procedures at the core. Saunders *et al*.'s (2009) research onion is illustrated in Figure 2.1:

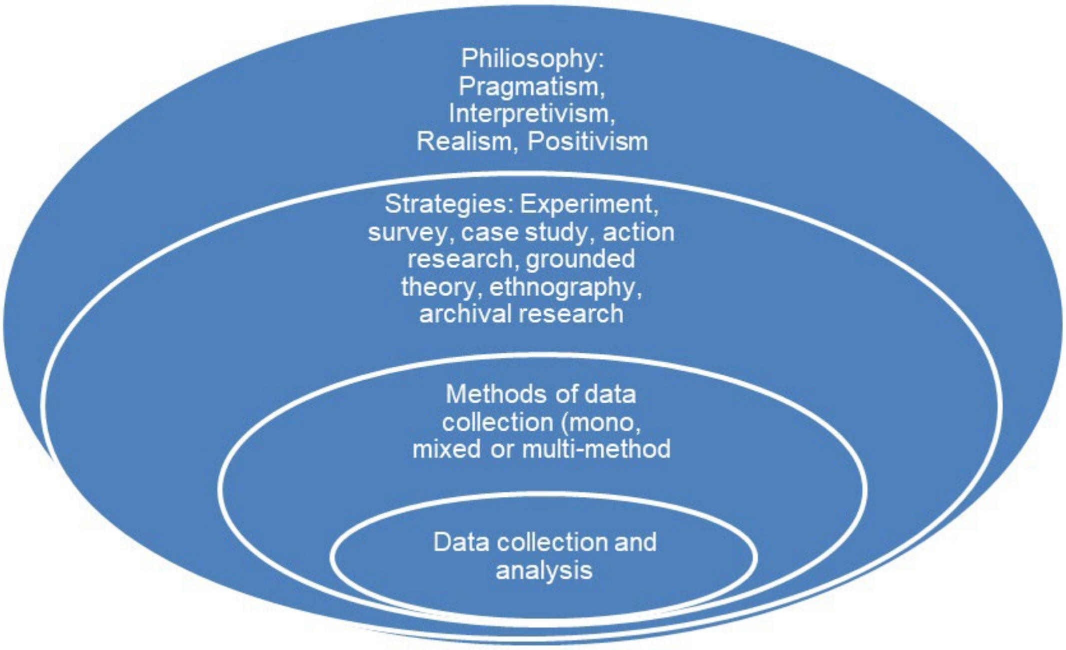

Figure 2.1: The research onion (derived)
Source: Saunders, Lewis and Thornhill (2009)

The philosophical choices that Saunders *et al*. (2009) gave are pragmatism, interpretivism, realism and positivism. The choice between only interpretivism (or qualitative) and positivism (or quantitative) philosophies is often debated. The most important determinant of the philosophy is the research question. For this research, the research question indicates a quantitative philosophy.

The research approach chosen is inductive and is supported by an experimental strategy demonstrated by a multi-method for collecting and analysing data. The research design, tools and plan encompassing the sampling method, data analysis methods, and the methods applied for validating and interpreting the research findings are elaborated on in the following sections.

2.2 RESEARCH DESIGN

The research is designed in three stages. The first stage entails an in-depth literature review that consists of three pertinent parts to straddle the multi-disciplinary nature of the study. The first part addresses the insurance environment related to buildings; the second creates the link between the insurance environment and the built environment; and the third interrogates cost modelling applied in the built environment. The literature review is sourced from textbooks, academic journal articles, legislation and industry-related electronic publications.

The second stage involves executing the empirical study by following a positivist or quantitative research philosophy to uncover objective realities rationally and logically (Carson *et al.,* 2001). Data is generated by applying various research instruments to develop a ratio scale for evaluating the cost model input factors.

The data is analysed and tested for validity and reliability during the third stage through machine learning and mathematical techniques.

The research plan in Figure 2.2 illustrates the processes to be followed.

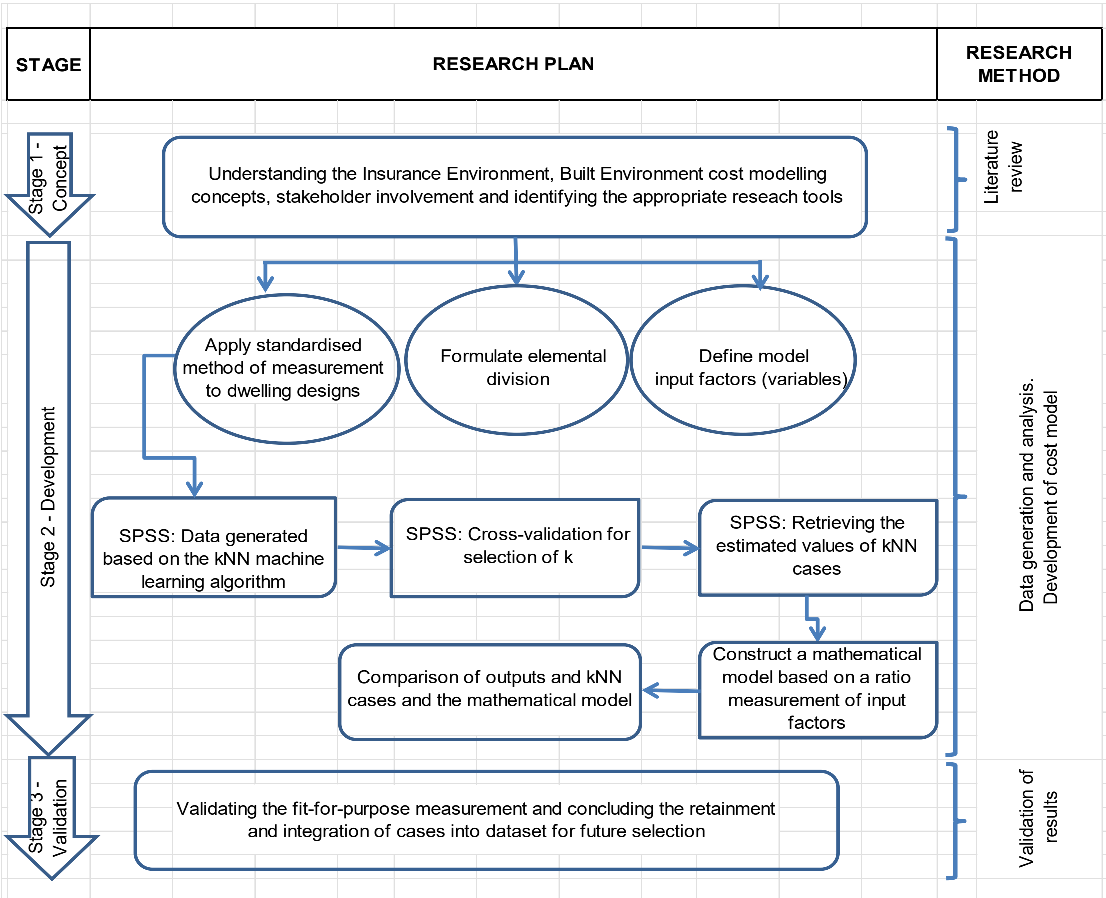

Figure 2.2: Research Plan
Source: Author's own

2.3 RESEARCH METHODOLOGY

2.3.1 Research instruments

The research instruments applied during the research are discussed below to illustrate their purpose and reliability.

The primary data is generated by quantifying the different residential buildings according to a recognised trade-based built environment standardised measurement system and applying standardised rates to the measured quantities to derive the monetary values for the residential buildings. After that, the trade-based information is converted into appropriate element-based information for analysis.

The specific research instruments applied in the process are the following:

- The Standard Systems of Measuring Building Work (7^{th} Edition), (ASAQS, 2015). As the title infers, it is a standardised measurement system designed to produce a uniform basis for compiling bills of quantities used for tender purposes in South Africa. The literature study extensively discusses the level of cost accuracy obtained by using this instrument.

- Specialised software commonly utilised in quantity surveying practices in South Africa; WinQS, was used to generate the bills of quantities.
- The tailor-made building elements for residential buildings derived from standardised Elemental Estimating Methods published by the Association of South Africa Quantity Surveyors combined with the elements suggested by the International Cost Management Standard (ICMS) (ICMS Coalition, 2021) that promotes global consistency in presenting construction costs.

2.3.2 Data sampling and data collection

2.3.2.1 Population

The research focuses on stand-alone single-storey residential buildings. Individual homeowners of these types of residences are the ones who require accurate replacement values of their properties for insurance purposes.

To grasp the extent of the population of the residential market research undertaken by Statistics South Africa (Stats SA, 2014c), the Property Sector Charter Council (PSCC) and the Centre for Affordable Housing Finance in Africa (CAHF) are considered. According to studies conducted by the PSCC in 2012 and 2015, the residential property sector is the most significant contributor to property value in South Africa. The values of the different sectors were as follows:

Table 2.1: Extent of Property Sector in South Africa

	VALUE OF PROPERTY SECTOR	2012	2015
1	Residential property	R3 trillion	R3.9 trillion
2	Commercial property	R780 billion	R1.3 trillion
3	Public property	R570 billion	R237 billion
4	Zoned urban land	R520 billion	R520 billion
	TOTAL	R4.9 trillion	R5.8 trillion

Source: Derived from Property Sector Charter Council (2017)

Evident from the information contained in Table 2.1 is that the entire property market value grew by 18% from 2012 to 2015, while the residential property sector grew by 30% over the same period. Where the residential property sector represented 61% of the entire property market in 2012, the representation increased to 67% in 2015.

Although the value for the residential properties given by the PSCC is not broken down into the different types of residential properties, such as stand-alone properties, sectional title properties or high-rise residential properties, it is known that stand-alone properties far outweigh the other types of properties. This is verified by the information in the General Household Surveys (P0318) conducted by Statistics South Africa on an annual basis since 2002 (Stats SA, 2002 to 2017) and the selected building statistics of the private sector as reported by local government institutions (P5041.3). According to these statistical releases, the statistics for building plans passed, and buildings completed, confirm the dominance of the residential market and the preference for stand-alone dwelling houses. The development trends for the years from 2010 to 2020 are illustrated in Tables 2.2 and 2.3:

Table 2.2: Value of building plans passed

	Total value (R millions)	Residential	Additions and alteration	Non-residential	Split for residential		
					Dwelling houses	Flats and townhouses	Other
2010	62 601	42.6%	37.5%	20.0%	75.0%	21.1%	3.9%
2011	66 566	43.9%	32.1%	24.0%	74.0%	24.5%	1.5%
2012	72 797	45.3%	30.9%	23.8%	71.9%	26.2%	1.9%
2013	86 118	44.4%	28.3%	27.3%	71.3%	25.1%	3.6%
2014	96 554	48.0%	26.3%	25.8%	69.0%	28.5%	2.5%
2015	101 590	49.8%	26.5%	23.8%	68.1%	30.0%	1.9%
2016	111 933	50.3%	25.1%	24.6%	60.9%	35.2%	3.9%
2017	115 550	48.9%	26.8%	24.3%	63.1%	35.5%	1.4%
2018	118 711	52.0%	24.9%	23.0%	53.6%	43.4%	2.9%
2019	109 345	50.7%	27.7%	21.6%	55.2%	43.4%	1.4%
2020	74 823	52.2%	27.8%	20.0%	61.6%	37.5%	0.8%

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020) (derived).

On average, the residential market represents 48.0% (range between 42.6% and 52.2%) of the total value for building plans approved, with stand-alone dwelling houses representing 65.8% (range between 53.6% and 75.0%) of the residential market or 31.58% of the total value of building plans approved.

Table 2.3: Value of buildings completed

	Total value (R Millions)	Residential	Additions and alteration	Non-residential	Split for residential		
					Dwelling houses	Flats and townhouses	Other
2010	43 844	47.9%	25.7%	26.4%	67.4%	26.9%	5.8%
2011	42 929	49.8%	26.7%	23.5%	73.3%	22.7%	4.0%
2012	44 974	51.3%	26.1%	22.6%	73.3%	25.4%	1.3%
2013	52 226	49.6%	23.4%	27.0%	70.3%	27.8%	1.9%
2014	52 814	52.9%	17.8%	29.3%	71.0%	27.2%	1.9%
2015	56 691	56.8%	17.3%	25.9%	72.1%	26.3%	1.5%
2016	61 417	57.0%	17.1%	26.0%	68.2%	30.1%	1.7%
2017	73 371	52.9%	15.8%	31.3%	61.7%	32.4%	5.9%
2018	73 416	60.6%	16.8%	22.7%	52.3%	46.2%	1.5%
2019	88 979	59.0%	14.9%	26.1%	55.3%	43.6%	1.1%
2020	49 103	52.1%	20.5%	27.4%	57.6%	40.8	1.3%

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020) (derived).

On average, the residential market represents 53.6% (range between 47.9% and 60.6%) of the total value for buildings completed, with stand-alone dwelling houses representing 65.7% (range between 52.3% and 73.3%) of the residential market or 35.2% of the total value of buildings completed.

Apart from considering only the representation of stand-alone dwelling houses to the overall value of approved building plans and completed buildings, it is also necessary to consider the sizing of the dwelling houses. The overall square meterage, number of units, and square meterage categories of the dwelling houses for building plans approved are given in Tables 2.4 to 2.6 and for buildings completed in Tables 2.7 to 2.9.

Table 2.4: Square meterage of building plans passed for residential properties

Year	Residential (m^2)	Non-residential (m^2)	Alterations and Additions (m^2)
2010	6 107 496	2 866 901	4 895 395
2011	6 342 158	3 160 394	4 260 813
2012	6 379 965	3 340 529	4 182 259
2013	6 831 551	4 351 797	4 250 420
2014	7 668 770	4 046 209	4 207 753
2015	7 929 121	3 794 875	4 052 559
2016	7 809 014	4 313 628	3 809 475
2017	8 150 210	3 864 348	3 796 603
2018	8 254 725	3 831 857	3 770 705
2019	7 286 893	3 319 067	3 641 211
2020	5 133 597	2 076 061	2 527 255

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020).

Table 2.5: Number of units of building plans passed for residential properties

Year	Dwelling houses (number of units)	Flat and Townhouses (number of units)	*Other (number of units)
2010	35 637	12 275	143
2011	38 096	14 728	94
2012	34 375	15 445	121
2013	34 097	16 350	154
2014	37 838	18 981	153
2015	39 764	20 215	134
2016	33 217	23 045	149
2017	35 598	24 226	168
2018	31 722	28 799	152
2019	27 144	21 817	162
2020	21 519	16 468	106

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020).

Table 2.6: Sizes in categories of building plans passed for residential properties

Year	< 30 m^2	30 m^2 < 80 m^2	> 80 m^2	Total
2010	145	20 607	14 885	35 637
2011	29	22 538	15 529	38 096
2012	74	17 719	16 582	34 375
2013	244	17 650	16 203	34 097
2014	22	20 695	17 121	37 838
2015	20	22 763	16 981	39 764
2016	45	17 273	15 899	33 217
2017	184	20 102	15 312	35 598
2018	28	16 645	15 049	31 722
2019	106	13 829	13 209	27 144
2020	20	11 309	10 190	21 519

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020).

Table 2.7: Square meterage of buildings completed for residential properties

Year	Residential (m^2)	Non-residential (m^2)	Alterations and Additions (m^2)
2010	5 009 046	2 438 186	2 583 421
2011	4 825 726	1 996 996	2 456 063
2012	4 858 809	2 322 246	2 016 669
2013	4 974 489	2 546 459	2 387 731
2014	4 795 822	2 520 176	1 617 737
2015	5 198 186	2 328 040	1 592 091
2016	5 165 318	2 406 060	1 602 197
2017	5 346 188	3 016 460	1 571 083
2018	5 940 063	2 282 082	1 556 797
2019	6 691 380	3 010 192	1 601 223
2020	3 242 704	1 848 604	1 148 335

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020)

Table 2.8: Number of units of buildings completed for residential properties

Year	Dwelling houses (number of units)	Flat and Townhouses (number of units)	*Other (number of units)
2010	29 714	10 965	57
2011	30 962	9 545	43
2012	31 592	11 386	34
2013	28 974	12 511	42
2014	26 194	11 849	39
2015	28 173	11 493	49
2016	27 796	13 731	40
2017	24 966	14 048	45
2018	22 377	17 825	66
2019	19 832	25 513	35
2020	13 993	10 185	24

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020).

Table 2.9: Sizes in categories of buildings completed for residential properties

Year	< 30 m^2	30 m^2 < 80 m^2	> 80 m^2	Total
2010	603	18 255	10 856	29 714
2011	46	19 460	11 456	30 962
2012	66	19 957	11 569	31 592
2013	88	17 348	11 538	28 974
2014	11	15 433	10 750	26 194
2015	69	15 943	12 161	28 173
2016	281	15 281	12 234	27 796
2017	10	14 154	10 802	24 966
2018	15	11 647	10 715	22 377
2019	22	9 814	9 996	19 832
2020	27	7 503	6 463	13 993

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020).

According to the CAHF, the South African residential property market for the period 2014 to 2017 comprised categories as set out in Table 2.10:

Table 2.10: **South African residential market size from 2014 to 2019**

Year	Number of properties	Value of properties	Value of residential properties	Number of residential properties	% of properties valued below R600 000	% of properties valued below R300 000
2019	7.4 million	N/A	N/A	6.6 million	56%	N/A
2018	N/A	N/A	N/A	N/A	N/A	N/A
2017	7.2 million	R6.8 trillion	R5.1 trillion	6.4 million	58%	35%
2016	7.1 million	R6.5 trillion	R4.7 trillion	6.2 million	54%	37%
2015	6.7 million	R5.8 trillion	R3.9 trillion	5.9 million	61%	41%
2014	6.7 million	R5.2 trillion	n/a	5.8 million	63%	42%

Source: Centre for Affordable Housing Finance in Africa (2015, 2016, 2017, 2018, 2019 and 2020)

The value of R3.9 trillion (for 5.9 million properties) for residential properties in 2015 is corroborated by the PSCC and the CAHF. The latest available data by the CAHF indicates that the value of affordable residential properties at the end of 2017 was R5.1 trillion (for 6.4 million properties). Although this value indicates market value and not replacement value, as required for insurance purposes, it is a good indicator of the magnitude of the value for insurance purposes.

Furthermore, it is noteworthy that the changed residential properties' values for the period from 2014 to 2017, is that smaller houses' (less than R 300 000 in value) representation decreased significantly from 42% to 35%, while the affordable houses' (less than R 600 000 in value) representation decreased slightly from 63% to 58%. The decreases are indicative of increased wealth.

2.3.2.2 Data sampling

Selecting a sample is arguably the most essential aspect of the research, as the sampling method indicates the representativity and generalisability of the sample relative to the population. In the previous section, the extent of the residential population was discussed. It is thus apparent that probability sampling is neither practical nor economical for this research; hence, a non-probability sampling method in the form of quota sampling is followed. This method entails that the proportions of specific strata within the population are mirrored in the sample (Welman *et al*., 2005).

The existing residential property population is expressed in value as R3,9 trillion for 2015. No information is available to establish the different sizes of the entire population. For the purposes of this research, the trends in the building plans approved and buildings completed over the last eight years are adopted as the indicator of strata.

The strata considered are the sizes of single residential units. The criteria for selecting the units are the proportion of residential units smaller than 30 m^2, between 30 and 80 m^2 and larger than 80 m^2. Furthermore, the proportions of building plans passed and buildings completed are considered.

Table 2.11: Proportional contribution according to the size of units of building plans passed for residential properties

Year	< 30 m^2	30 m^2 < 80 m^2	> 80 m^2
2010	0.4 %	57.8 %	41.8%
2011	0.1 %	59.2%	40.7%
2012	0.2 %	51.6%	48.2%
2013	0.7 %	51.8%	47.5%
2014	0.1 %	54.7%	45.2%
2015	0.1 %	57.2%	42.7%
2016	0.1 %	52.0%	47.9%
2017	0.5 %	56.5%	43.0%
2018	0.1%	52.5%	47.4%
2019	0.4%	50.9%	48.7%
2020	0.1%	52.6%	47.3%
Average	0.3%	54.3%	45.5%

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions 2010 to 2020 (derived).

Table 2.12: Proportional contribution according to the size of units of a building completed

Year	< 30 m^2	30 m^2 < 80 m^2	> 80 m^2
2010	2.0 %	61.4 %	36.6%
2011	0.1 %	62.9%	37.0%
2012	0.2 %	63.2%	36.6%
2013	0.3 %	59.9%	39.8%
2014	0.0 %	58.9%	41.1%
2015	0.2 %	56.6%	43.2%
2016	1.0 %	55.0%	44.0%
2017	0.0 %	56.7%	43.3%
2018	0.1%	52.0%	47.9%
2019	0.1%	49.5%	50.4%
2020	0.2%	53.6%	46.2%
Average	0.4%	57.2%	42.4%

Source: Statistics South Africa, Statistical release P5041.3: Selected building statistics of the private sector as reported by local governments institutions (2010 to 2020) (derived).

From the proportional contribution for approved building plans and completed buildings illustrated in Tables 2.11 and 2.12, the approved building plans lag the completed buildings. The trend in the sizes of the residential properties evidently leans towards residences between 30 m^2 and 80 m^2. The contribution of residences smaller than 30 m^2 is negligible; thus, residences larger than 30 m^2 are used to generate the primary data, and in a proportional relationship of, on average, 54.3% of building plans approved, and 57.2% of residences completed should be between 30 m^2 and 80 m^2 in size and 45.5% of building plans approved and 42.4% of residences completed should be larger than 80 m^2.

The units within the different strata are, however, obtained incidentally. Therefore, the likelihood of the sample being adequately representative of the population is reasonably high (Welman *et al*., 2005).

The residential building designs used to generate the primary data are obtained from a quantity surveying practice specialising in insurance cases, housing developers and individual homeowners.

2.3.2.3 Data analysis

Quantitative research usually constitutes a form of experimental research. Such research requires some form of intervention where the dependent variables (or units of analysis) are measured before and after the intervention so that the intervention's influence on the dependent variables can be determined (Welman *et al*., 2005).

In this research, the CBR methodology is deployed. The method is the process of solving new problems by adapting or intervening in solutions used to solve old problems (Riesbeck & Schank, 1989; Perera & Watson, 1998).

The apparent advantage of CBR is thus the employment of previous case experiences in the process of creating new cases. The solved old problems in this research are the cases generated based on the standardised measuring and estimating methods still commonly applied in quantity surveying practices. A two-stage machine learning algorithm and mathematical model intervention are applied. Firstly, the kNN algorithm selects the best-fit values for the dependent variables. Secondly, a mathematical intervention based on ratio scales of design factors is applied. Ultimately, the replacement costs of the kNN cases in the dataset are compared to the estimated replacement costs after the interventions to evaluate the accuracy obtained.

2.3.2.4 Validity and reliability of the research

2.3.2.4.1 Reliability

The reliability of the research is a measure of the consistency, transparency, clarity, and extent to which the research can be regenerated by any party other than the researcher (Leedy & Ormrod, 2010). The research tools employed in this research to generate the primary data are thoroughly entrenched in quantity surveying practice, the sound machine learning analytic techniques performed, and the transparent development of the mathematical ratios all contribute to demonstrating the reliability of the research.

2.3.2.4.2 Validity

The validity of a measuring tool is determined by the extent to which the tool measures what is intended (Leedy & Ormrod, 2010). Validity is measured at different levels. For experimental research, internal validity is significant, as it indicates the extent to which any change in any of the dependent variables influences the independent variable. Thus, removing any factors that could threaten the internal validity is very important. In this research, the desired outcome to establish the ability of the independent variables to positively influence the accuracy of the dependent variable through machine learning and mathematical interventions is demonstrated.

External validity is obtained by the extent to which the sample represents the population. The understanding of the population for this research is extensively explained in Section 2.3.2.1. The selection of the sample is thus carefully managed to ensure appropriate representation.

2.4 INTERPRETATION OF RESEARCH FINDINGS

2.4.1 Findings in relation to literature

The literature first outlines the principles and procedures applied in the insurance environment to understand the requirements for insuring assets, specifically residential properties. Secondly, the link between the insurance environment and the built environment cost modelling is established. Thirdly, the built environment cost modelling is interrogated to create the requirement of developing a cost model specifically applicable to producing accurate replacement values for residential buildings. The research findings and conclusions with respect to the development of the cost model are consistent with addressing the insurance gap, as stated in the literature.

2.4.2 Findings in relation to practice

The relationship between the research findings and quantity surveying practice is established by utilising recognised quantity surveying techniques in generating the primary data.

The development of the proposed cost model is motivated by the consequences of underinsurance observed in practice. The need identified by the researcher is informed by processes currently employed by insurance companies, firstly, when the insurance cover is implemented and, more importantly, when damage is incurred. The proposed cost model constitutes the determination of improved estimation for insurance purposes. It is found that the proposed cost model has application value in practice. Although this research intends to create a cost model for insurance purposes, the technique can also be applied to estimation for other purposes.

2.5 SUMMARY

As discussed in Chapter 2, the research methodology laid the foundation for the focused literature review to commence in Chapters 3 to 5. These chapters will explain the insurance environment, the quantity surveying environment, and the built environment, and how the two environments interact with each other. The development of the data and its presentation and in-depth analysis in the process of creating the model to address the underinsurance of residential buildings is set out in Chapters 6 and 7.

CHAPTER 3: THE INSURANCE ENVIRONMENT

3.1 THE ORIGIN OF INSURANCE

In early times, the practice of informal risk-sharing and risk mitigation was based on the solidarity of societal structures often grouped according to guilds, trades, associations, or village communities. Seafaring nations mitigated risks by distributing cargo amongst different ships. It soon became apparent that the informal nature of risk-sharing and risk mitigation rapidly reached its limits.

Italian merchants invented the first formal insurance contract in the fourteenth century. The concept of insurance was known and practised long before then but was first reduced to writing by the Italian merchants. The insurance contract spread around the world along with trade. Therefore, many countries have strong similarities in the nature and contents of insurance contracts and laws. The insurance contract is thus truly international, according to Birds, 2013; Van Niekerk, 1998a; Reinecke, *et al*., 2013; Millard, 2013.

Insurance was driven by practice rather than by legislation. Medieval lawyers were challenged by practice to classify the insurance contract so that it could be taken up in the legal system and thus be regarded as legal. Roman-Dutch lawyers persisted in equating the characteristics of insurance contracts to other forms of contracts rather than identifying features unique to insurance contracts. Insurance contracts were most frequently equated to contracts of sale based on the reciprocal nature and the transference of risk in both types of contracts. The interpretation, therefore, was that the insured sells the risk related to their property to the insurer. In return, the insurer accepts the risk by receiving the payment of an insurance premium from the insured (Van Niekerk, 1998a).

This simplistic view was problematic in the sense that purchasing the risk was / is not the prime objective of insurance. The prime objective is rather the promise to indemnify the insured should the risk materialise. As insurance contracts became more entrenched in practice, the focus turned to identifying characteristics unique to insurance contracts rather than equating specific characteristics to other forms of familiar contracts (Van Niekerk, 1998a).

Although South African law is based on the Roman-Dutch law introduced in South Africa with the 1652 settlers, it is not codified like most European continental legal systems that also have their roots in Roman-Dutch law. Due to the history of our country, our law is considerably influenced by English law (Havenga *et al.*, 2013). This is also the case with insurance law and, thus, South African insurance contracts and practices.

The development of building insurance was driven by one distinct disaster, namely the Great London Fire in 1666. More than 13 000 houses, 87 churches, 44 livery halls and the historical city gates were totally destroyed, and the Guildhall, St Paul’s Cathedral, Barnyard’s Castle and the Royal Exchange were severely damaged by the fire (Redeal, 2016; Haueter, 2013). A Londoner, Dr Nicholas Barbon, made a fortune rebuilding houses from 1666 to 1692. He also established an insurance company called the “Insurance Office for Houses” in 1667 to mitigate his risk exposure to the mortgage loans issued to rebuild homes destroyed in the fire.

Barbon soon realised that premiums alone would not generate sufficient funds to cover extensive losses. His experience as a banker enabled him to realise the need for a different financial approach to insurance. This led to the establishment of the first joint shares property insurance company known only as the “Insurance Offices” by Dr Nicholas Barbon and three associates in 1680. The first standardised fire insurance policy based on set rates was issued in 1681. The face value of the policies was based on fixed terms at a percentage of the house’s annual rental value. Were the houses destroyed, the company was compelled to pay the total face value. To gain the public’s confidence, a trust fund was established to guarantee the payment of losses (James, 1954; Haueter, 2013).

Barbon is regarded as the founder of modern fire insurance. Shareholding became essential for modern insurance, as it allowed the separation of operational capital from risk capital and provided funds for the further development of insurance.

3.2 DEFINING INSURANCE

No single definition of insurance exists, as it depends on which discipline's perspective it is defined. It could be viewed from a legal, economic, historical, actuarial science, risk theoretical or sociological perspective. For purposes of this study, the legal and economic perspectives are the most relevant. These viewpoints share common elements. The following definitions are highlighted to demonstrate the commonality globally:

Table 3.1: Definitions of insurance

Source	Definition
Commission on Insurance Terminology of the American Risk and Insurance Association in Redja & McNamara (2014)	Insurance is the pooling of **fortuitous** losses by **transfer of such risks** to insurers, who agree to **indemnify** insureds for such losses, provide other **pecuniary benefits** on their occurrence, or render services connected with risk.
Birds (2013)	A contract of insurance is any contract having as its principal object one party (the insurer) **assuming the risk of an uncertain event**, which is **not within its control**, happening at a future time, in which event the other party (the insured) has an **interest**, and under which contract the insurer is bound to **pay money or provide its equivalent** if the **uncertain event occurs**.
Lake v Reinsurance Corporation Ltd 1967 (3) SA 124 (W) Millard (2013)	A contract between an insurer and an insured, whereby the insurer undertakes in return for the **payment of a price or premium** to render to the insured a **sum of money, or its equivalent**, on the happening of a specific **uncertain event** in which the insured has some **interest.**

The highlighted aspects contained in these definitions are discussed in detail at a later stage.

3.3 THE NATURE AND CLASSIFICATION OF INSURANCE

3.3.1 Nature of insurance

Transferring and spreading the risk amongst many individuals exposed to the same risk and prepared to make small contributions towards neutralising the detrimental effects of risks that any one of them could suffer is one of the economically most satisfactory methods of creating financial security (Birds, 2013).

Adam Smith (1776), whose work is regarded as the foundation of classic economics, stated that "… the trade of insurance gives great security to the fortunes of private people, and, by dividing amongst a great many that loss which would ruin an individual, makes it fall light and easy upon the whole society."

On the matter of purchasing insurance, Smith (1776) opined that "… how moderate, however, as the premium of insurance commonly is, many people despise the risk too much to care to pay it." He further stated that the "… neglect of insurance upon shipping, however, in the same manner as upon houses, is, in most cases, the effect of no such nice calculation, but of mere thoughtless rashness, and presumptuous contempt of the risk."

The nature of the insurance business is that most insureds will not receive anything back from their policies in any given period. People's unrealistic expectations about insurance often leave them disgruntled. People choose insufficient insurance to keep premiums low and are unhappy when their damages are not fully covered. On the contrary, insureds view insurance as a bad investment if they do not receive returns. These views exist because people lose sight of the real goal of purchasing insurance. The view should rather be that the best return is no return at all, as this would indicate that no loss occurred and that financial protection is assumed to be in place against a potential loss (Kunreuther *et al.*, 2013).

After all, insurers are profit-driven companies that need to compete against each other for business while creating peace of mind and value for money for the consumers of insurance products. They will, therefore, not be charitable and approach people in distress (Millard, 2013).

In recent years, the United Nations (UN) has placed much emphasis on the sustainability of the different spheres within modern society. This is no different for the insurance environment. Under the leadership of the United Nations Environment Programme's Financial Initiative (UNEP FI), the Principles for Sustainable Insurance (PSI) were launched at the Rio+20

Conference (UNEP FI, 2012). The four principles deal with issues that insurers should subscribe to in order to deliver sustainable insurance products and create a sustainable insurance industry.

The first principle is to embed environmental, social and governance (ESG) issues relevant to the insurance business into decision-making by establishing company strategies to identify, manage and monitor ESG issues in business operations; integrate the identification and assessment of ESG issues into risk management and underwriting processes; develop products and services that reduce risk; improve claims management through quick, fair, sensitive and transparent responses to clients and ensure that processes are understood and ESG issues are integrated into the repair and replacement processes and other claims services; ensure that marketing staff understand the products and services coverage and how ESG issues related to the products (UNEP FI, 2012).

The second principle is to work together with clients and business partners to manage risk, develop solutions and raise awareness of ESG issues by discussing the benefits of managing ESG issues with clients and suppliers and supplying them with the tools and information to manage the ESG issues and promote the adoption of the PSI to insurers, reinsurers and intermediaries (UNEP FI, 2012).

The third principle is to work together with governments, regulators and other key stakeholders to promote action on ESG issues throughout societies by supporting policies and regulatory and legal frameworks that instil better management of ESG issues and risk reduction measures and engage governments and regulators to develop integrated risk management strategies and risk transfer solutions (UNEP FI, 2012).

The fourth principle is to demonstrate accountability and transparency by regularly disclosing the PSI implementation progress through assessing, measuring and monitoring the companies' progress in managing ESG issues and regularly making the information available to the public; participating in reporting frameworks and engaging clients, regulators and other stakeholders to gain a mutual understanding of the value of disclosure according to the PSI (UNEP FI, 2012).

As discussed later, these principles are now entrenched in South African legislation and regulations.

3.3.2 Classification of Insurance

Diverse types of insurance and insurance contracts are classified according to the nature of the insurer's performance, the legal nature of the insurer, the nature of the insured, the nature of the event insured against, the nature of the interest insured and the nature of and purpose with the contract

(Reinecke, *et al.,* 2013). The most common classifications are briefly discussed:

3.3.2.1 Non-profit or For-profit Insurance

Insurers are either non-profit (mutual insurers) or for-profit (shareholding or share capital insurers). A mutual insurance company is wholly owned by its insureds and acts in the best interest of its insureds, whereas a share capital insurance company is a publicly traded corporation owned by its shareholders and generates profit for its shareholders and not policyholders or insureds. Based on an insurance company's status as a mutual or share capital insurer, the company is obliged to either be unincorporated without share capital or be a public company that carries on the insurance business as its main aim. Most insurance companies today are share capital insurers (Reinecke *et al.,* 2013).

3.3.2.2 Personal or Business Insurance

The distinction between personal and business insurance is drawn for regulatory purposes. Consumer protection regulations apply to personal insurance but not to business insurance. The distinction is specifically important concerning the Financial Advisory and Intermediary Services Act no. 37 of 2002, hereafter referred to as the FAIS Act (RSA, 2002) as the Act distinguishes between personal and commercial assets to generate an income (Reinecke *et al.,* 2013; Millard, 2013).

3.3.2.3 Indemnity or Non-indemnity Insurance

The aim of indemnity insurance is that the insurer places the insured in the position the insured was before the loss occurred. Bettering the insured's position is not permitted. The insured is thus compensated for a specific loss either by repairing, replacing or paying a specific determinable amount. Indemnity insurance applies to non-personal issues such as property.

Non-indemnity insurance is based on a pre-determined amount stipulated in the contract that is paid when the risk insured materialises. Non-indemnity insurance applies to personal matters that cannot be repaired or replaced, for example, death or ill health (Reinecke *et al.,* 2013; Millard, 2013; Havenga *et al*., 2013).

3.3.2.4 Life and Non-life Insurance

The distinction between life insurance and all other insurances is well established in insurance practice and law. The distinction lies in the certainty or uncertainty of the insured event occurring. Death is certain, but what is uncertain is when it will occur. With non-life insurance, there is no certainty that a risk will occur. Therefore, non-life insurance is generally indemnity insurance that compensates insureds only in the event of loss suffered (Birds, 2013; Reinecke *et al.,* 2013).

Life insurance and non-life insurance classification pertains globally except in the United States of America (USA) and South Africa. In the USA, non-life insurance is termed property and casualty insurance (Rejda & McNamara, 2014).

South Africa has a unique classification of long-term and short-term insurance, as chosen by the legislature. The distinction is based on the type of risk insured. Long-term insurance refers to life policies, disability policies, and so on, whereas short-term insurance refers to short-term policies, as stipulated in the legislation, such as property policies, motor policies, engineering policies, transport policies, accident and health policies, liability policies, guarantee policies and miscellaneous policies (Reinecke *et al.,* 2013; RSA, 1998b). Essentially, short-term insurance is deemed indemnity insurance and long-term insurance is deemed non-indemnity insurance (Millard, 2013) and, therefore, is like non-life and life insurance.

This research is thus concerned with personal, indemnity, non-life, and short-term insurance.

3.4 ESSENTIALS OF INSURANCE

For any insurance relationship to come into being, some fundamental legal principles must exist. These principles are called the essentialia of a contract and are terms that distinguish insurance contracts from other types of contracts. These are the principles of indemnity, insurable interest, subrogation and utmost good faith (Rejda & McNamara, 2014; Thoyts, 2010; Birds, 2013; Reinecke *et al.*, 2013; Havenga *et al*., 2013).

It is often difficult to distinguish between the rule of law and the principles of insurance. An insurance system can only operate properly if the fundamental principles are applied properly. The principles must thus be supported by law. The essentialia mentioned above indeed give effect to the principles of insurance, which are the transfer of risk, pooling of common risks and the determination of equitable premiums (Thoyts, 2010).

3.4.1 Principle of Indemnity

From the onset, the premise of indemnity insurance was k insured against. The traditional indemnity theory of common law, as taken up in Roman-Dutch, Anglo-American and South African insurance law, dictates that the insured takes out insurance to protect their financial position, and the insurer intends to indemnify the insured for the monetary loss suffered; nothing more than the monetary loss.

What was not so clear was what the limit of the indemnity was. The limit of indemnity is introduced into the contract by including an insured sum. The sum insured is the main factor considered when determining the premium. It is the maximum amount that can be recovered from the insurer in the case of a total loss or a proportionate part of it, if it is a partial loss (Thoyts, 2010; Reinecke *et al.*, 2013; Van Niekerk, 1998b).

A further limiting measure is an excess clause, or deductible clause, that requires the insured to carry a specified first amount of the loss. This clause intends to discourage small claims with high administrative costs (Reinecke *et al*., 2013).

3.4.1.1 Undertaking by the Insurer to Compensate Insured

For non-indemnity insurance, the compensation would be a predetermined amount that the insurer will be compelled to pay. For indemnity insurance, the insurer is obliged to pay a determinable amount of money that can only be determined after an occurrence. For any indemnity claim to succeed, the insured must prove that they suffered a loss caused by an insured peril (Reinecke *et al*., 2013; Havenga *et al*., 2013).

The original measure of indemnity was taken up in the "*Wetboek van Koophandel*", which is the document that contains the codification of the Dutch and Roman-Dutch commercial law. Article 288-1 mentions a monetary payment, reinstatement, or rebuilding. Article 288-2 describes the measure of indemnity as the difference between the value of the object directly before the loss and the value of the object directly after the loss in the case of a partial loss (Van Niekerk, 1998b).

The four methods instilled in early law are still practised in modern times. Usually, insurers have the discretion to choose which method would be the best in different circumstances. These methods are monetary compensation, repair of damaged property, replacement of damaged property, and reinstatement of the damaged property. The chosen indemnity method is usually dictated by the extent of the damage (Thoyts, 2010; Reinecke *et al.*, 2013).

The distinction between replacement and reinstatement lies in the fact that replacement relies on the principle of old-for-new, which exceeds the narrow interpretation of indemnity; for example, if a house contained carpets from a range that has since been discontinued, a carpet of a certain quality is replaced by a carpet of similar quality, while reinstatement means that exactly the same should be rebuilt. If reinstatement is impossible, the insured will be paid the sum insured (Birds, 2013).

The damage could either be partial or total. What is recoverable is the property's value at the date of the loss, subject to the sum insured. Where there is partial damage to buildings, the choices would be either a cash settlement or repair of the damage. Replacement value insurance operates on a new-for-old basis, exceeding the narrow patrimony view. The replacement value and the market value of general goods, for example, the contents of a dwelling, such as electronic equipment, are similar. The insured would thus be indemnified if they receive a monetary sum to purchase equivalent goods or whether the insurer replaces the goods. The situation with replacing totally destroyed buildings is more complex, seeing that the rebuilding cost could either exceed the market value or be less than the property's market value depending on the economic cycle at the time of the damage. This cost disparity raises the question of whether reinstatement can apply because this would put the insured in a better position than before the damage, hence overcompensating the insured, which is contrary to the indemnity principle. The current thinking is that the principle of indemnity should be adapted to suit modern conditions and needs (Birds, 2013; Reinecke *et al*., 2013).

3.4.1.2 Risk and the Transfer thereof

Individuals constantly face risk. Prior experiences of loss influence the propensity to accept or avert risk. The existence of risk is the basic driver of insurance, and the degree of risk aversion is the driver behind the amount of insurance purchased (Thoyts, 2010).

Every insurance contract depends on a measure of uncertainty of an event occurring in the future. Uncertainty is defined as a risk by the probability of a peril causing the damage. The risk insured against must be described to such an extent that the insurer knows the nature of the risk, and the insured knows the extent of the cover. The insurer must be able to calculate the insurability of the risk by determining the possibility and probability of loss (Reinecke *et al*., 2013). The description must thus include the object insured, for example, a house, the hazard insured against, for example, fire, storms, earthquakes, and so on, and any circumstances that affect the risk, for example, the exclusion of land subsidence (Reinecke *et al*., 2013; Havenga *et al.*, 2013).

The risks are personal risks that cannot be transferred. It is the financial consequence of the risk that is transferred. From a legal point of view, an insurance contract is viewed as an individual arrangement between the insurer and the insured. In reality, insurers are financial intermediaries that manage the relationship between many risks and the common pool (Thoyts, 2010).

The relationship is illustrated as follows:

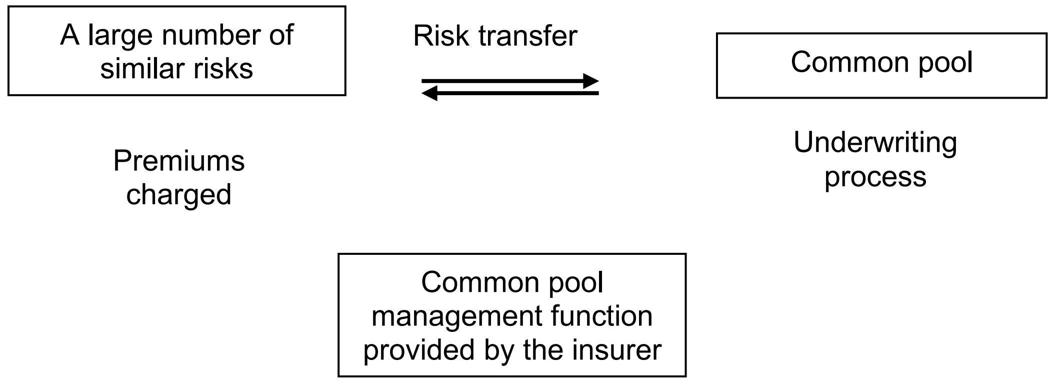

Figure 3.1: The insurance concept (Thoyts, 2010)

3.4.1.3 The Common Pool

The general premise is that the risks are transferred to the insurer. In reality, the risks are transferred from several individuals to the common pool. The term common pool refers to the similar nature of the pooled risks (Thoyts, 2010). The losses incurred by a few are spread over the entire group by pooling the risks. The purpose of pooling the risks is to reduce the variation in possible outcomes. The variation, measured in standard deviation, diminishes as the pool grows larger, although the expected loss remains constant (Rejda & McNamara, 2014). The following simple example illustrates the principle:

Two homeowners own properties valued at R 1 500 000 each. Assume there is a five percent probability that either property is totally destroyed in an independent event. Each owner's expected annual loss is R 75 000 with a variance of R 326 917 if each one carries their own risk.

Expected loss: (0.95 x R0) + (0.05 x R1500 000) = R75 000

Variance (standard deviation): $\sqrt{0.95(0 - 75\,000)^2 + 0.05(1\,500\,000 - 75\,000)^2}$ = R326 917

Should the two homeowners agree to share their risk and equally contribute to any possible loss, there are four possible outcomes: none of the homes is damaged, the first owner's home is damaged, the second owner's home is damaged, or both homes are damaged. The probabilities for each outcome are as follows:

none of the homes are damaged	0.95 x 0.95 = 0.9025
first owner's home is damaged	0.05 x 0.95 = 0.0475
second owner's home is damaged	0.95 x 0.05 = 0.0475
both homes are damaged	0.05 x 0.05 = 0.0025

If none of the homes is damaged, each owner loses R0. If one home is damaged, each owner's loss is R750 000; if both homes are damaged, each owner's loss is R1 500 000. The expected loss for each owner remains R75 000.

Expected loss: (0.9025 x R0) + (0.0475 x R750 000) + (0.0475 x R750 000) + (0.0025 x R1 500 000) = R75 000

The variance, however, decreases from R326 917 to R231 166 due to the reduced probabilities of the extreme values R0 to R1 500 000

Variance: $\sqrt{0.9025\ (0 - 75\,000)^2 + 0.0475\ (750\,000 - 75\,000)^2 + 0.0475\ (750\,000 - 75\,000)^2 + 0.0025\ (1\,500\,000 - 75\,000)^2} = R231\,166$

Adding each individual to the common pool reduces the probabilities of losses and variance between losses.

3.4.1.4 The Premium

The insured undertakes to pay a premium, usually a sum of money. The premium payment is not a requirement for creating an insurance contract, but payment is usually a suspensive condition for the policy to take effect. Due to the premium being an essential feature of an insurance contract, it is not possible to provide insurance free of charge (Reinecke *et al*., 2013; Havenga *et al.*, 2013).

Due to the immense price rivalry, the underwriting performance for non-life (property and casualty) insurers is very important. Setting the prices is also regulated to be adequate to cover the losses; prices must not be excessive and must not be unfairly discriminatory.

Determining premiums, which is the pricing of the insurance cover, is very different from other products. With other products, the production cost is known in advance. Thus, adequate allowances can be included in the pricing. With insurance products, the cost is not known in advance. Gross premiums that the insureds pay are compiled from pure premiums (cover for loss and adjustment costs) plus loading (administrative expenses, profit and contingencies) multiplied by the exposure (risk or probability of a loss occurring). Premiums for non-life policies are also determined by applying class rating techniques. Classifications for buildings are typically the construction material, dwelling age, fire protection installations, and so on. The two techniques applied in determining the premium are either the pure premium method or the loss ratio method. With the pure premium method, the incurred loss and loss adjustment expenses are divided by the number of actual losses that occurred in a specific underwriting period, for example, the losses and adjustment costs over a year are R4 500 000 and 4 500 events occurred, the pure premium would be R4 500 000 / 4 500 = R1 000. Assuming a loading factor of 40%, the gross premium would be R1 000 / 1 – 0.40 = R1 667 (Rejda & McNamara, 2014; Vaughan & Vaughan, 2014).

The loss ratio method entails comparing the actual loss ratio to the expected loss ratio and adjusting the price accordingly. Assume the same actual loss as before of R4 500 000 and the premiums received were R5 000 000. The actual loss ratio is thus R4 500 000 / R5 000 000 = 90%. Assume that the expected loss ratio is 80%, the price needs to be adjusted (increased) by

12.5% ((0.90 – 0.80) / 0.80 = 12.50%) (Rejda & McNamara, 2014; Vaughan & Vaughan, 2014).

3.4.1.5 Double Insurance

Double insurance occurs when the same interest is insured by the same insured against the same risks and the same loss with two or more insurers. An insured is entitled to insure the same risk with several insurers but is only entitled to recover the amount of loss. The recovery will be pro-rated to the cover with each insurer. The insured will thus be compensated but will not profit. Double insurance often results in over-insurance. Insurers attempt to counter fraud by including compulsory notification of double insurance in their contracts (Birds, 2013; Reinecke *et al.*, 2013; Millard, 2013; Havenga *et al*., 2013).

3.4.1.6 Over-insurance

An insurer can insure risks for larger than necessary amounts but will only be compensated the value of the loss when an event occurs (Havenga *et al*., 2013). Over-insurance could be intentional, where the value of the risk is expected to increase during the period of insurance, but generally, it is a waste of premium if it is not intended (Reinecke *et al.*, 2013).

3.4.1.7 Under-insurance and Average

Under-insurance has an old history dating back to the sixteenth century when compulsory under-insurance existed. This was specifically so in the context of marine insurance, where merchants were prohibited from purchasing full-value insurance. The prohibition intended to prevent the situation of over-insurance. This legislation was not popular with insureds and insurers alike and was largely ignored in practice. The gradual relaxation and eventual abolition of the legislation indicate the importance of insurance in business practice, as it evolved from simply aiding business to being an indispensable part of the business. Under-insurance was, however, still applied voluntarily as it would result in a lower premium. The insured is regarded as their own insurer for the underinsured amount and thus carries the proportionate part of the loss (Van Niekerk, 1998b).

Where insureds are insured for an amount less than the actual value of the risk, they are under-insured. The insured is obliged to ensure that the sum insured keeps pace with the value and / or cost of the replacement of their property. Failure to do so could result in the insurer avoiding liability because of non-disclosure of a material fact or applying the principle of average (Birds, 2013).

Average clauses commonly contained in insurance contracts determine that an insured will be compensated pro-rata for a loss. The sum insured determines the ratio as a proportion of the property's actual value. Therefore, if an insured is only insured for 50% of the value, the compensation will be only 50% of the claim. Because the sum insured is the basis for calculating the premium, insureds could be tempted to deliberately reduce the sum insured to lower the premium. The average clause intends to discourage under-insurance (Thoyts, 2010; Reinecke *et al*., 2013; Millard, 2013; Havenga *et al*., 2013).

The proof that under-insurance exists vests with the insurer. Proof must be produced for the insurer to apply the average clause. The application of the average clause is criticised as unfair in cases where under-insurance is not intentional. In German law, the average is only applied where the sum insured is considerably less than the actual value. In the United Kingdom (UK), the average clause is rarely applied to domestic household contracts. The average clause is common to South African domestic household contracts; therefore, insurers introduce automatic increases in accordance with inflation rates. In some instances, there is also a limitation to the average provision of a certain proportion, for example, if the sum insured falls within, say, 80% of the actual value, the average is not applied (Reinecke *et al*., 2013).

According to Reinecke *et al.* (2013), applying the average clause in cases where under-insurance is not intentional has not been tested in any case of law in South Africa (Reinecke *et al*., 2013).

3.4.2 Insurable Interest

The principle of an insurable interest dates back to the Middle Ages. The intention was to distinguish between wagers and indemnity insurance. Initially, the interest was intended to serve as a measure of loss or damage, but gradually, the interpretation changed to an essential of an insurance contract. This has been taken up in English law, and several South African judgements have supported this view, although it is not taken up in South African law (Reinecke *et al*., 2013; Rejda & McNamara, 2014).

The insured needs to be able to demonstrate financial loss to claim compensation. An insurable interest can be created in three ways: by common law, for example, ownership; by contract, for example, a tenant of a property who is not the owner but is made responsible for the upkeep of the property; and by statute, for example through a mortgage (Birds, 2013).

To have an insurable interest means that the insured must have a particular relationship with the object of risk. Loss or damage is thus defined regarding the insurable interest, and the insurable interest is used to determine whether an insured has suffered loss or damage. Thus, the insurable interest distinguishes an insurance contract from a wagering contract (Thoyts, 2010; Birds, 2013; Havenga *et al*., 2013).

3.4.3 Subrogation

Subrogation applies to all indemnity contracts. The principle gives the insurer the right of recourse against a third party after the insured is indemnified. Proceedings are conducted in the name of the insured. Subrogation intends to prevent the insured from profiting from insurance by claiming indemnity from the insurer and suing the third party for damages. It also ensures that the cost of the loss is passed onto the responsible party or their insurer (Thoyts, 2010; Birds, 2013; Millard, 2013; Havenga *et al*., 2013; Rejda & McNamara, 2014).

3.4.4 Utmost Good Faith

The *uberrima fides* rule, or rule of utmost faith, first formally brought into the common law by Lord Mansfield in 1766 through his judgement in the Carter vs Boehm case, is the cornerstone of all global insurance relationships. The rule determines that both the insurer and the insured are obliged to declare all material facts about the risk being insured (Larkin, 1995; Lobo-Guerrero *et al*., 2013). The word utmost suggests that parties to an insurance contract should be more frank and forthcoming with information and display a higher degree of honesty than parties to other commercial contracts (Reinecke *et al*., 2013; Rejda & McNamara, 2014).

However, the principle of utmost good faith has recently been rejected from South African law; firstly because there is no such principle in the Roman-Dutch law; and secondly, the interpretation is that there cannot be degrees of good faith. Good faith remains a crucial factor in determining the content of insurance contracts (Reinecke *et al.*, 2013).

The principle of good faith thus applies to pre-contractual negotiations where the insured is expected not to misrepresent facts and to disclose all material facts when completing a proposal form for insurance. The insurer is required to refrain from supplying incorrect information and to furnish all information in its possession (Havenga *et al*., 2013).

In general, the premise is that the insured possesses all the information about the risk and that the insurer needs to be informed accordingly. This position is based on two highly debatable assumptions. The first assumption is that the information is exclusively within the insured's knowledge, and the second assumption is that the insurer is unaware of the information or unable to obtain it. Under South African law, an insured is only required to disclose facts that are within their knowledge and they are not obliged to seek further knowledge. If any such information provided is untrue, it is not regarded as wrongful (Reinecke *et al*., 2013).

The traditional application of the principle of good faith has substantially been modified by modern consumer protection legislation. Consumer-centric regulation tends to balance the responsibility to act with utmost good faith between the parties. This is apparent from the fair treatment of customers regulation discussed later on.

3.4.4.1 Misrepresentations

A misrepresentation is a deliberate act to create a misperception based on an incorrect or misleading statement regarding a material fact that leads to the conclusion of a contract (Reinecke *et al*., 2013; Havenga *et al.*, 2013).

Representations must be viewed either as fact or opinion. Representation of opinion could be incorrect, but there could be reasonable grounds for the insurer to have adopted the opinion. This could typically be the case where the insured amount is much lower than the actual value of the risk object (Birds, 2013).

3.4.4.2 Non-disclosures

Non-disclosure occurs when an insured deliberately withholds information and does not correct an impression concerning a material fact (Havenga *et al.*, 2013).

Under South African law, the basic rule is that there is no obligation on contracting parties to disclose negative or positive information, but in the context of insurance contracts, the insured is required to disclose facts that are relevant to the risk that the insurer is to assume. The insurer will thus have a defence against an insured's claim if the relevant facts are not disclosed (Reinecke *et al*., 2013).

3.5 INSURANCE INDUSTRY REGULATION

The insurance industry is regulated to maintain insurer solvency, compensate for inadequate consumer knowledge, ensure reasonable premiums and make insurance available. The solvency is important because premiums are paid in advance, but the protection period is in the future. The solvency thus ensures that insurers can honour their promise in the future. Insurance contracts are complex documents riddled with technical and legal clauses and provisions; therefore, the protection of consumers is crucial (Rejda & McNamara, 2014).

The South African Law of Insurance has a chequered history. Disputes arising from insurance contracts are governed by the general principles of the Roman-Dutch law that arrived in South Africa with the Dutch settlers but are strongly influenced by precedents of English law since the British occupation early in the nineteenth century. The adoption of the English precedents resulted from the absence of similar precedents in the Roman-Dutch law at the time. It is, therefore, still the case that matters of a general nature, such as the validity of a contract, its conclusion, interpretation, performance, breach, and so on, are governed by Roman-Dutch law and aspects specific to insurance contracts, such as insurable interest, good faith, over-insurance, under-insurance, reinsurance, and so on, are adopted from English law (Reinecke *et al.*, 2013). These specific aspects are discussed in more detail at a later stage.

The South African insurance industry is regulated by the Financial Services Board Act 97 of 1990 (FSBA), hereafter referred to as the Financial Services Board Act or FSBA (RSA, 1990), which oversees non-banking financial services. The Financial Services Board (FSB) takes its regulatory mandate from twelve different acts. The acts that pertain specifically to the insurance industry are the Constitution of the Republic of South Africa No. 108 of 1996, hereafter referred to as the Constitution of South Africa (RSA, 1996), the Consumer Protection Act No. 68 of 2008 (amended and enforced on 31 March 2011), hereafter referred to as the Consumer Protection Act (or CPA) (as amended) (RSA, 2011), the Long-term Insurance Act no. 52 of 1998 (or LTIA), hereafter referred to as the Long-term Insurance Act (RSA, 1998a), the Short-term Insurance Act No. 53 of 1998 (or STIA), hereafter referred to as the Short-term Insurance Act (RSA, 1998b) and the FAIS Act (or FAISA) (RSA, 2002) implemented on 30 September 2004 (Burling & Lazarus, 2011).

The LTIA and the STIA are the division between non-indemnity and indemnity insurance contracts. The distinction is determined by the nature of the loss, which is either a patrimonial or a non-patrimonial loss. Damage or loss is restricted to patrimonial loss (Reinecke *et al.,* 2013). A patrimonial loss is a financially calculable loss that arises when a peril occurs (Millard, 2013). Thus, with indemnity insurance contracts requiring patrimonial loss, the insurers seek to compensate for the damage the insured suffered. The compensation according to indemnity insurance contracts fluctuates according to the severity of the damage and the insured amount. Examples hereof are property insurance such as fire and theft. With non-indemnity insurance, also referred to as capital insurance, insurers undertake to compensate the insureds a fixed amount of money, as a non-patrimonial loss does not have an economic value. Thus, they cannot restore the non-patrimonial loss, but can merely provide relief for the beneficiaries (Millard, 2013). Examples of such contracts are life insurance and personal accident insurance (Havenga *et al*., 2013). For purposes of this research, the focus is on indemnity insurance.

3.5.1 The Constitution of the Republic of South Africa, 1996

The Bill of Rights, chapter 2 of the Constitution of the Republic of South Africa, 1996, gives effect to the intention of the Constitution to "…. (a) heal the divisions of the past and establish a society based on democratic values, social justice and fundamental human rights, …. (c) improve the quality of life of all citizens and free the potential of each person …" by dealing with primary rights such as equality, human dignity and several freedoms and secondary rights such as housing, health care, food, water, social security and education (RSA, 1996; Havenga *et al*., 2013).

Insurance coverage is inherently based on inequalities because premiums are calculated on the strength of stereotyping, such as age, gender, location, and so on, and individuals are even denied insurance coverage if their risk profiles are perceived to be too high (Burling *et al.,* 2011).

3.5.2 The Consumer Protection Act 68 of 2008

The Consumer Protection Act intended to introduce a single comprehensive legal framework for consumer protection (Havenga *et al*., 2013). The act thus introduced statutory protection for consumers by establishing national norms and standards for contracts between suppliers and consumers of goods and services (Burling *et al.,* 2011), directly influencing the relationships in the short-term insurance supply chain.

Eight rights were introduced, namely equality in the consumer market, right to privacy, right to choose, right to disclosure and information, right to fair and responsible marketing, right to fair and honest dealing, right to fair, just and reasonable terms and conditions and the right to fair value, good quality and safety (RSA, 2011; Havenga *et al*., 2013).

The Act, through its definition of “service”, excludes all advice regulated by the FAISA and any underwriting or assumption of any risk by one person on behalf of another regulated by the LTIA (RSA, 1998a) and the STIA (RSA, 1998b). The exclusion is, however, subject to the proviso that the insurance industry aligns itself with the conditions of the CPA. Until alternative regulations are in place, the terms of the CPA also apply to the LTIA and the STIA. The alternative regulations are discussed at a later stage.

3.5.3 Short-term Insurance Act 53 of 1998

The STIA regulates the registration of short-term insurers, their financial arrangements, business practices, policies and policyholder protection, while the FAISA regulates the activities of advisors and intermediaries that act on behalf of the short-term insurers (Burling *et al.,* 2011; Reinecke *et al*., 2013; Millard, 2013).

3.5.4 Financial Advisory and Intermediary Services Act 37 of 2002

The activities of insurance industry intermediaries such as brokers, agents, loss adjusters, and the like are regulated under this act.

3.5.5 Financial Services Board regulations

Perceived unfair business practices necessitate the global tendency to develop more stringent regulation of financial services. The focus has been to change business practices from product-centric practices relying on tick-box compliance to customer-centric ones focusing on customer satisfaction.

It is thus an outcomes-based approach (RSA National Treasury, 2014). The development of South African regulations is aligned with international standards through its G20 membership. The G20 membership is a forum for international co-operation between 19 countries and the European Union's leaders, finance ministers and central bank governors.

3.5.5.1 Twin peaks system

The modern approach to the legislation, regulation and supervision of financial services is called the twin peaks approach. This refers to prudential and market conduct regulation. Prudential regulation aims to maintain the solvency and liquidity of organisations, thus ensuring their safety and continued financial health. Market conduct regulation regulates how firms conduct their business, design and price their products and treat their customers to protect them and promote public confidence in the financial system. The implementation of the Twin Peaks system is imminent. The prudential regulation will become the responsibility of the South African Reserve Bank, and the market conduct regulation will remain the responsibility of the FSB. The Netherlands and Australia have already implemented twin peaks systems, while the UK is moving towards this step. Other countries have incorporated elements of the system in their regulations, for example, France has combined banking and insurance in the same regulation. South Africa has gained valuable insight through the shared experiences with the Netherlands, Australia, the UK, Canada and the USA (Financial Regulatory Reform Steering Committee, 2013).

Although closely related, the sources of prudential and conduct risks are very different, hence the need to separate the supervision thereof (RSA National Treasury, 2014; Financial Regulatory Reform Steering Committee, 2013).

3.5.5.2 Treating Customers Fairly (TCF) Framework

The cornerstone of the market conduct regulation is the TCF framework. The TCF framework was first published in March 2010, and the intended implementation was from 2014 onwards. Although the implementation was delayed, it has been rolled out. According to Millard (2016), the legal status of the TCF principles is debatable, but now that the TCF principles have been included in the regulatory framework, courts cannot just apply the law but will also have to measure the TCF principles against the six outcomes as outlined in Table 3.2. The TCF framework implementation is not a once-off event but an incremental process (FSB, 2014). Although the FSB closely followed the guidance of the FSA in the UK, the FSB made it clear from the onset that the South African process would be an outcomes-based framework as opposed to the principles-based framework applied in the UK (Visser & Van Wyk, 2016). The six outcomes set for the TCF framework are as follows:

Table 3.2: **Treating Customers Fairly Framework Outcomes**

OUTCOMES	DESCRIPTIONS
1	Give customers confidence that they are dealing with firms where the fair treatment of customers is central to corporate culture.
2	Ensure that products and services are marketed and sold in the retail market designed to meet the needs of identified customer groups.
3	Provide customers with clear information and keep them informed before, during and after the time of contracting (policy).
4	Strive that the advice is suitable and takes account of the customer's circumstances.
5	Ensure that products sold to customers perform (within reasonable limitations) as firms have led them to expect and that the associated service is of an acceptable standard.
6	Safeguard against customers facing unreasonable post-sale barriers imposed by firms to change products, switch providers, submit claims or complain.

Source: FSB (2014): Treating Customers Fairly

The FSB conducted a readiness survey pre-implementation of the TCF framework from December 2012 to August 2013 to determine the readiness of each different sector under the FSB's mandate. A self-assessment tool based on the six TCF framework outcomes was used to measure how customer treatment practices measured up against the outcomes.

The overall readiness of short-term insurers was rated at 65%, with the individual outcomes scoring as set out in Table 3.3. The survey incorporated two additional questions to test the risk management frameworks concerning outcomes 2 to 6. The first question asked whether risks that impact the organisation's ability to adhere to the TCF outcome have been identified and are managed actively. The second question sought to establish whether concrete examples supported by management information could be provided to prove the extent to which the TCF outcome is met.

Table 3.3: **Treating Customers Fairly Framework: Self-assessment readiness results for short-term insurers.**

OUTCOMES	READINESS RESULTS	ADDITIONAL QUESTIONS AFFIRMATIVE ANSWERS
1 (Culture and governance)	56%	-
2 (Products and services)	63%	40%
3 (Clear and appropriate information - disclosure)	75%	43%
4 (Suitable customer advice)	72%	33%
5 (Performance and services)	70%	43%
6 (Claims, complaints and product changes)	75%	40%
OVERALL	65%	

Source: Adapted from FSB (2013). ***TCF implementation and baseline study feedback report***

Visser and Van Wyk (2016) conducted a survey on the claims processes and procedures of the largest South African short-term insurer to explore the level of compliance since the implementation of the TCF framework. Their results reflected the following:

Table 3.4: **Largest South African short-term insurer's level of compliance with the Treating Customers Fairly Framework**

CRITERIA	RESPONSE
Understanding the regulation	80% of staff received training
Regulation impact on staff	67% of staff confirmed observing changes in company conduct and culture change since 2014
Treating customers fairly	65% of staff agreed that the regulation would have a profound impact on the company's future conduct. 93% of staff confirmed that management is serious about and committed to TCF and constantly talks about it
Fairness to clients	53% of respondents indicated that the regulation would override their current insurance contracts. 81% of respondents consider regulation before processing claims
Prescribed method to follow when handling complaints	64% of respondents indicated that they know how to handle complaints
Measurement and reward	60% of respondents indicated that TCF now forms part of their performance appraisal process

Source: Adapted from Visser and Van Wyk (2016). ***The impact of the treating customers fairly legislation on the short-term insurance industry: Santam claims specific.***

Visser and Van Wyk (2016) concluded that compliance with the TCF framework required continuous training and improved organisational communication, not just within specific departments.

3.5.5.3 Policyholder protection rules

The Policyholder Protection Rules (PPRs) that came into operation on 01 January 2018 is promulgated in terms of Section 55 of the STIA to give effect to the required changed business conduct of the TCF framework.

The PPRs provide for the following:

- Fair treatment of policyholders and sets out the requirements that incorporate the outcomes of the TCF
- The design of products and the determining of premiums and excesses
- Advertising and disclosure
- Arrangements with intermediaries and distribution of products
- Product performance and acceptable service through data management, ongoing performance review and proper record-keeping
- No unreasonable post-sale barriers through proper claims management, complaints management and policy termination (RSA, 2017a).

With the promulgation of these PPRs, the STIA has fulfilled the requirement of the CPA that sectors exempted from the CPA conditions need to publish their alternative conditions. The PPRs conditions are regarded to be more stringent than the CPA conditions.

3.5.5.4 Solvency assessment and management (SAM)

Financial performance is evaluated according to the relationship between the assets and liabilities of the insurance company. The assets are straightforward and consist of the usual financial instruments such as bonds, shares, real estate, securities, cash, and so on. The liabilities, however, are much more complex because of the reversed delivery process. This means that the income is earned at the current time, but the liability is payable somewhere in the future. Due to this reversed delivery process, the solvency of insurance companies is regulated and closely monitored to ensure that the company can cover future losses, thus protecting policyholders (Rejda & McNamara, 2014).

The regulation prescribes two kinds of financial reserves: loss reserves and unearned premium reserves. Loss reserves cover the costs of losses that have already occurred and for which the claims have been adjusted but have not been settled. These claims have been reported but have not been adjusted, as well as for losses that have occurred, but claims have not been submitted at the time of drawing up the financial statements. Unearned premium reserves are the total of all gross premiums on all outstanding policies at the time of drafting the financial statements. The purpose of this reserve is to pay for losses during the policy period, refund policyholders pro-rata when coverage is cancelled, and forward to reinsurers (Rejda & McNamara, 2014). Other less complicated liabilities are brokers' commission, loss-adjusting expenses, staff remuneration, general operating expenses and tax.

Another reserve that can be regarded as the balancing item in the financial statements is the policyholder's surplus, which is the difference between the assets and the liabilities. This surplus could be utilised to pay for actual losses. This surplus is created from earnings on investments (interest, dividends and rental income) and retained operating income. The extent of the surplus is a good indicator for the new business to be written.

The financial performance of insurance companies is measured in the loss ratio, expense ratio, combined ratio, investment income ratio and overall operation ratio. Each of these ratios is expressed as follows:

Loss ratio = (incurred losses + adjustment expenses) / premiums earned

Expense ratio = underwriting expenses/premiums written

Combined ratio = loss ratio + expense ratio

Investment income ratio = net investment income / earned premiums

Overall operating ratio = combined ratio – investment income ratio

Where the combined ratio is less than one, there is an underwriting profit, but when it exceeds one, there is an underwriting loss. An underwriting loss can be offset against the investment income ratio to achieve an overall profit (Rejda & McNamara, 2014).

3.5.6 Insurance Act 18 of 2017

The Insurance Act 18 of 2017, hereafter referred to as the Insurance Act (RSA, 2017b), came into effect on 18 January 2018. This act replaces parts of the LTIA and the STIA to incorporate the prudential regulation of conduct and supervision of insurance business to be aligned with the Constitution of the Republic of South Africa and to international standards for insurance regulation and supervision (RSA, 2017b).

3.6 SUMMARY

The literature review was conducted to understand the legal framework from which insurance contracts take their mandate. The insurance contract is evidently international, although the essentialia are interpreted slightly differently under different countries' laws.

The definition of an insurance contract in the South African context is adopted to be as follows: "A contract between an insurer and an insured, whereby the insurer undertakes in return for the payment of a price or premium to render to the insured a sum of money, or its equivalent, on the happening of a specific uncertain event in which the insured has some interest."

The key role that insurance plays in the preservation of an individual's wealth is indisputable. The crux of this preservation lies in the insurer rendering the insured a sum of money or its equivalent, which encapsulates the principle of indemnity. The determination of the sum insured, which forms the basis for the calculation of the premium, and the principles of under-insurance and average are of specific importance in the context of this research.

The shift from product-centric to consumer-centric insurance practices informed by the principles of sustainable insurance and reflected specifically in the market conduct regulation such as the treating customers fairly framework, which is also entrenched in the policyholder protection rules of the STIA, is a clear indication that insurers are obliged to offer products to insureds that are understandable, meet their needs, that insureds are kept informed throughout the insurance value chain and would not be faced by unfair post-sale practices.

CHAPTER 4: LINKING THE INSURANCE INDUSTRY AND THE BUILT ENVIRONMENT

4.1 INTRODUCTION

The insurance principles and the legal and regulatory framework of insurance were reviewed in the preceding chapter. This chapter aims to review literature that illustrates the gap between the insurance practice of for-profit personal indemnity non-life insurance and the need for a more accurate determination of the sums insured with a specific focus on residential properties.

The concept of insurance has developed to such an extent today that there is hardly a risk that cannot be insured against (Havenga *et al.*, 2013). Insurance thus cuts across all economic activities. The size of the insurance economic activity is expressed as a percentage of premiums written in relation to a country's gross domestic product (GDP). No consideration is, however, given to the total actual value insured.

According to Thoyts (2010), the developed world is heavily insured, and the developing world is very low if indeed insured. In 2010, the insurance premiums of the 30 members of the Organisation for Economic Development and Co-operation (OEDC) accounted for 86.5% of all insurance while the premiums of the USA alone equated to 29% of global premiums (Thoyts, 2010). Subsequently, the non-life insurance market share of the USA grew to 37.5% in 2016 (Insurance Information Institute, 2018).

4.2 INSTITUTIONAL SECTORS OF ECONOMIC ACTIVITY

The economic activities in South Africa are divided into nine sectors according to the Institutional Sector Classification Guide of South Africa (SARB, 2017). The classification is aligned with international standards. These sectors and their recent economic trends are as follows:

Table 4.1: South African economic sectoral trends

	Sector description	Percentage contribution to the South African GDP							
		2010	2011	2013	2014	2015	2016	2017	2018
1	Agriculture, hunting, forestry and fishing	2.5	2.4	2.4	2.5	2.4	2.4	2.6	2.6
2	Mining and quarrying	9.6	9.7	8.2	8.4	8.0	7.9	8.2	8.1
3	Manufacturing	14.6	13.4	12.6	13.3	13.0	13.4	13.5	13.5
4	Electricity, gas and water supply	2.8	2.9	3.0	3.7	3.6	3.7	2.3	2.3
5	Construction	3.8	4.5	3.7	4.1	4.0	4.0	3.8	3.8
6	Wholesale and retail trade, repair of motor vehicles, motorcycles and personal household goods, catering and accommodation	13.9	14.5	16.6	14.8	15.0	15.2	15.0	15.1
7	Transport, storage and communication	9.1	8.2	8.9	10.0	10.0	10.1	9.4	9.6
8	Financial intermediation, insurance, real estate and business services	21.2	21.2	21.5	20.5	20.9	20.2	22.3	22.4
9	Community, social and personal service	6.3	6.9	6.0	5.7	5.7	5.8	5.9	6.0
**	Government services	16.2	16.3	17.1	17.0	17.4	17.3	16.8	16.7
		100	100	100	100	100	100	100	100

Source: SARB (2017); IDC (2011, 2012, 2014, 2015, 2016, 2017,2018 and 2019)

The insurance industry belongs to the eighth sector, namely, financial intermediary, insurance, real estate, and business services, which has consistently contributed between 20 and 22% of South Africa's GDP from

2010 to 2018 and is the largest of the nine sectors. Although the insurance contribution is based on the direct input into the economy in terms of premiums paid, insurance has a much greater influence on the economy when the payments of insurance claims are considered. All industries benefit from insurance payouts, but the industries that noticeably derive a considerable portion of the benefit are the automotive, construction, and retail industries (Insurance Information Institute, 2017).

4.3 THE SIZE OF NON-LIFE INSURANCE MARKETS

Until recently, non-life insurance in South Africa was referred to as short-term insurance, as distinguished in the STIA. This changed with the enactment of the Insurance Act (RSA, 2017b). Globally, this type of insurance is referred to as non-life insurance, except in the USA, where it is referred to as property and casualty insurance. The lists of specific types of non-life insurance policies, also referred to as classes of insurance, that fall into this category are set out under the Insurance Act (RSA, 2017b) and the STIA (RSA, 1998a), are:

Table 4.2: Insurance classes for non-life insurance (Insurance Act 18 of 2017 and Short-term Insurance Act 53 of 1998)

Non-life classes, according to the Insurance Act	Short-term Insurance Act
• Motor • Property • Agriculture • Engineering • Marine aviation • Transport • Rail • Legal expense • Liability • Consumer credit • Trade credit • Guarantee • Accident and health • Miscellaneous • Reinsurance	• Accident and health • Engineering • Guarantee • Liability • Miscellaneous • Motor • Property • Transportation

These policy classes are sold as stand-alone or combined policies, also known as bundled policies. Bundling is performed to improve the combined risk of the policy. The products offered bundle their coverage (add several perils together) to increase the probability of any one of the bundled perils occurring. The bundling of perils increases the desirability of insurance products. Residential building insurance is offered under the property insurance class and is generally called homeowners' insurance (Rejda & McNamara, 2014; Vaughan *et al.*, 2014).

While the size of the insurance market is measured by the number of direct premiums written and expressed in relation to the GDP, the performance of the insurance market is measured by the market's penetration and density. The penetration is expressed as the ratio between the premiums written and the GDP as a percentage, whilst the ratio between the population illustrates the density and the GDP expressed as an amount per person in the population. Due to the relationship between the GDP and the insurance data, it is fair to say that the performance of the insurance market closely follows economic performance (Swiss Re, 2017).

To place the size and performance of the South African non-life insurance market into context, three groups of data were extracted from the data sets of the International Insurance Fact Books (Insurance Information Institute 2003, 2004, 2005, 2006-2007, 2008-2009, 2010-2011, 2012, 2013, 2014, 2015, 2016, 2017 and 2018) , the World Bank (The World Bank Group, 2016) and ~~the~~ Swiss Re (Swiss Re Institute 2012, 2015, 2017 and 2018) publications. The three groups are the G7, which consists of the seven most industrialised global economies: the USA, the UK, Canada, France, Germany, Italy and Japan; BRICS, which consists of Brazil, Russia, India, China and South Africa and Africa's four largest economies that are South Africa, Nigeria, Algeria and Egypt.

The specific data extracted pertains to the direct premiums written, the sizes of the populations, and the GDP to illustrate the penetration and density for each market. Figure 4.1 illustrates the direct premiums written in millions of USD for the G7 for the period from 2001 to 2016. The G7 contributed 62.66% of the premiums globally, of which the USA contributed 37.52%, Germany 5.69%, Japan 5.54%, the UK 4.96%, France 4.01%, Canada 3.05% and Italy 1.89% in 2016. The average annual premium growth for the period was 4% for the USA, 4.5% for Germany, 2% for Japan, 3.5% for the UK, 7% for France, 10% for Canada and 3% for Italy.

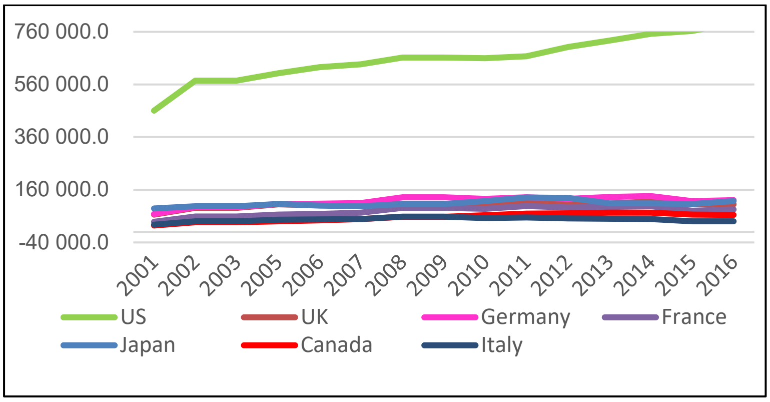

Figure 4.1: Direct premiums for G7, written in millions of USD

Figure 4.2 illustrates the direct premiums written in millions of USD for BRICS for the period from 2001 to 2016. BRICS contributed 13.01% of the premiums globally, of which China contributed 9.62%, Brazil 1.5%, India 0.83%, Russia 0.68% and South Africa 0.38% in 2016. The average annual premium growth for the period was 115% for China, 36% for India, 15% for Brazil, 14% for Russia and 9% for South Africa. The rapid growth in the Chinese premiums written is attributed to the launching of the first online insurance distribution.

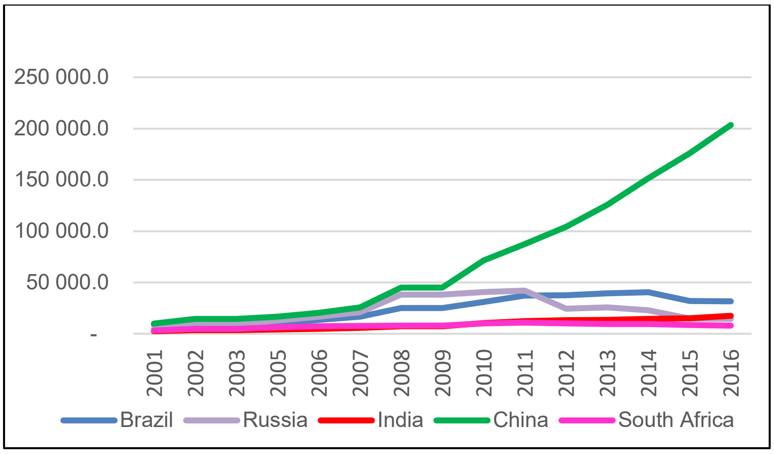

Figure 4.2: Direct premiums for BRICS, written in millions of USD

Figure 4.3 illustrates the direct premiums written in millions of USD for Africa for the period from 2001 to 2016. Africa contributed 0.52% of the tips globally, of which South Africa contributed 0.38%, Egypt 0.05%, Algeria 0.05% and Nigeria 0.04% in 2016. The average annual premium growth for the period was 18% for Algeria, 16% for Nigeria, 11% for Egypt and 9% for South Africa.

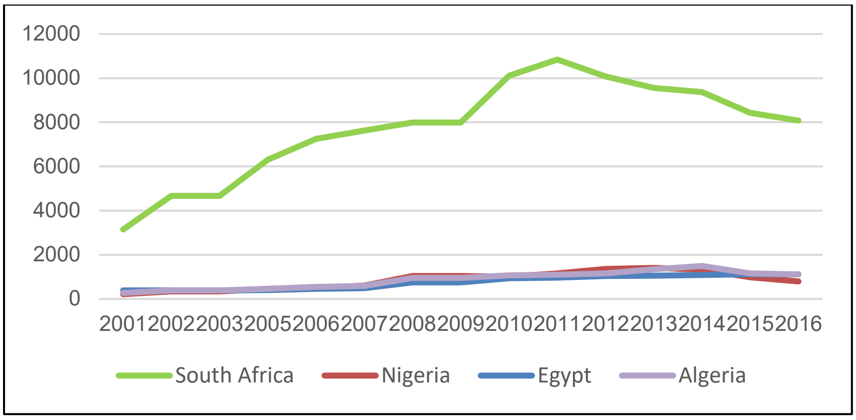

Figure 4.3: Direct premiums for Africa, written in millions of USD

Figure 4.4 illustrates the population in millions for the G7 for the period from 2001 to 2016. The population of the USA is 323 million, which is ranked 3rd largest globally; that of Japan is 127 million and ranked 11th largest globally; that of Germany is 83 million and ranked 18th largest globally; that of France is 67 million and ranked 22nd largest globally, that of the UK is 66 million and ranked 23rd largest globally, that of Italy is 61 million and ranked 24th largest globally and that of Canada is 36 million and ranked 39th largest globally.

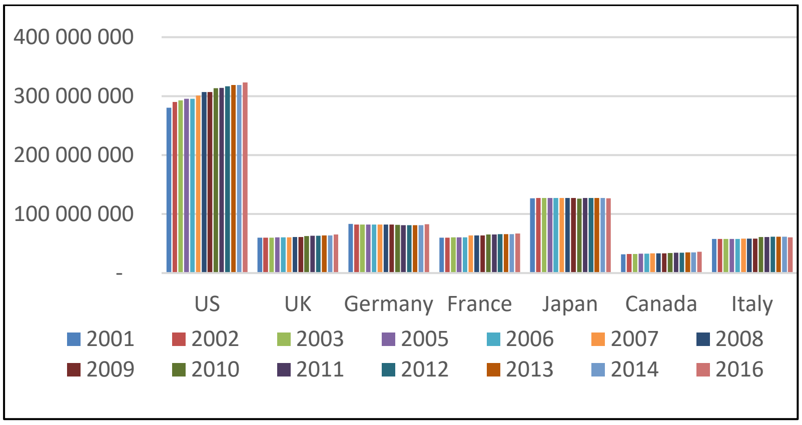

Figure 4.4: Population in millions for the G7 countries

Figure 4.5 illustrates the population in millions for BRICS for the period from 2001 to 2016. The population of China is 1 379 million, which is ranked the largest globally; that of India is 1 324 million and ranked 2nd largest globally; that of Brazil is 208 million and ranked 6th largest globally; that of Russia is 144 million and ranked 10th largest globally and that of South Africa is 56 million and ranked 26th largest globally.

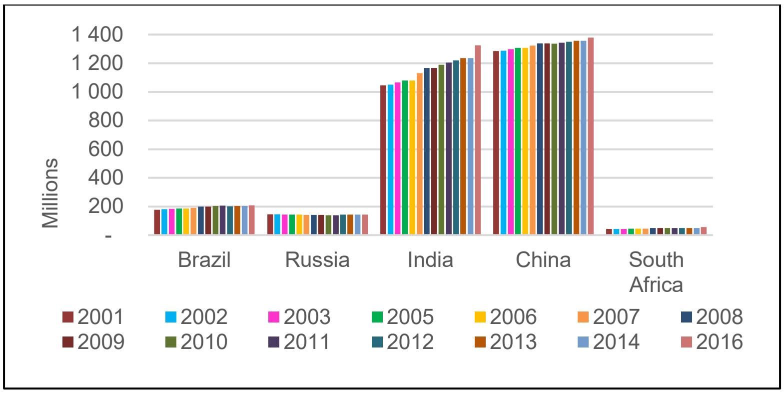

Figure 4.5: Population in millions for BRICS countries

Figure 4.6 illustrates the population in millions of Africa for the period from 2001 to 2016. The population of Nigeria is 186 million, which is ranked 8th largest globally; that of Egypt is 96 million and ranked 16th largest globally; that of South Africa is 56 million and ranked 26th largest globally; and that of Algeria is 41 million and ranked 34th largest globally.

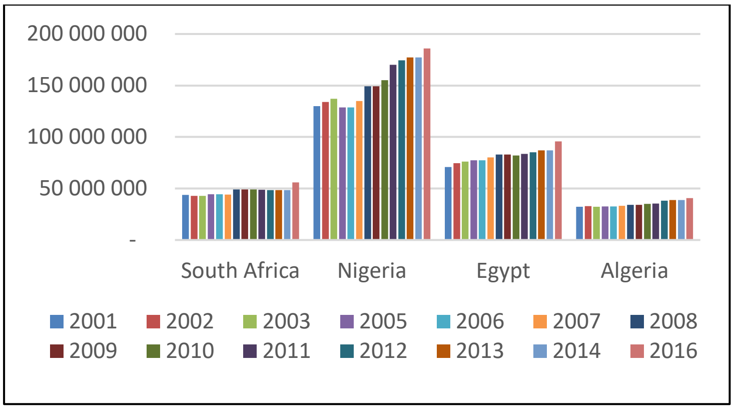

Figure 4.6: Population in millions for African countries

The GDP of the G7 as of 2016 is illustrated in Figure 4.7. The USA, with a GDP of US$18 624 billion is ranked 3rd highest globally, that of Japan is US$5 360 billion ranked 5th highest globally, that of Germany is US$4 090 billion ranked 6th highest globally, that of the UK is US$2 795 billion ranked 10th highest globally, that of France is US$2 766 billion ranked 11th highest globally, that of Italy is US$2 326 billion ranked 13th highest globally and that of Canada is US$1 619 billion ranked 16th highest globally.

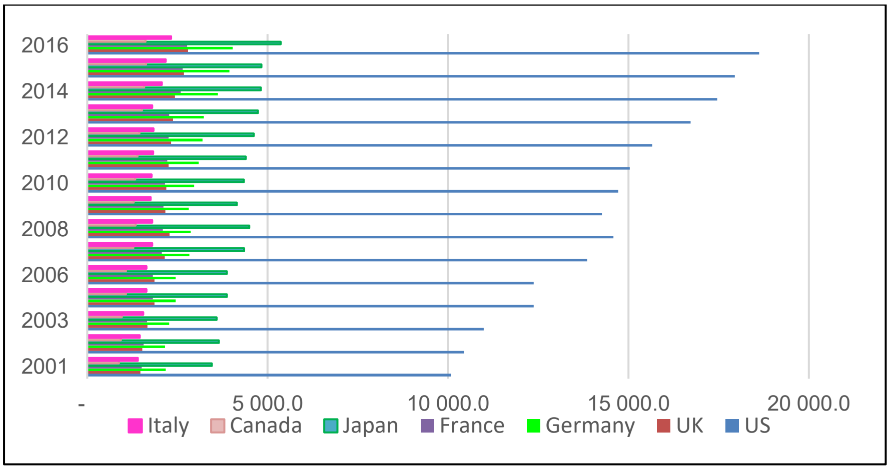

Figure 4.7: GDP in billions of USD for the G7

The GDP of BRICS in 2016 is illustrated in Figure 4.8. China with a GDP of US$21 409 billion is ranked the highest globally, that of India US$8 701 billion is ranked 4th highest globally, that of Russia of US$3 636 billion is ranked 7th highest globally, that of Brazil of US$3 141 billion is ranked 8th highest globally and that of South Africa of US$739 billion is ranked 31st highest globally.

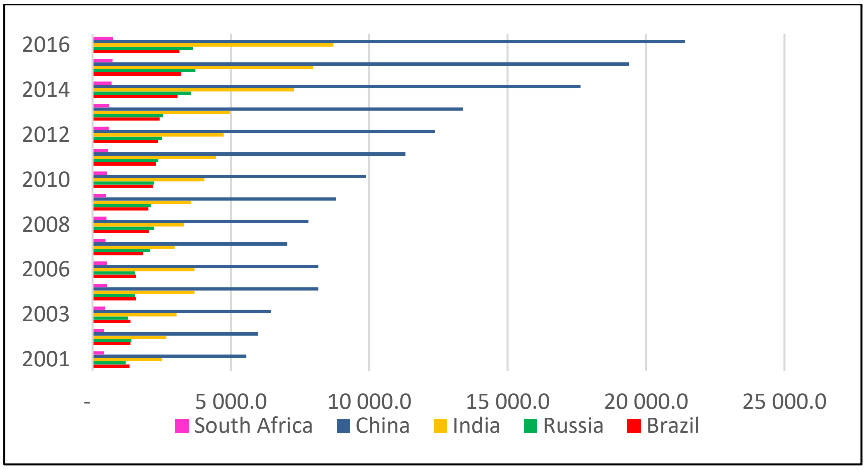

Figure 4.8: GDP in billions of USD for BRICS

The GDP of Africa in 2016 is illustrated in Figure 4.9. Nigeria with a GDP of US$1,090 billion is ranked 23rd highest globally, that of Egypt of US$1,065 billion is ranked 24th highest globally, that of South Africa of US$739 billion is ranked 31st highest globally and that of Algeria of US$610 billion is ranked 34th highest globally.

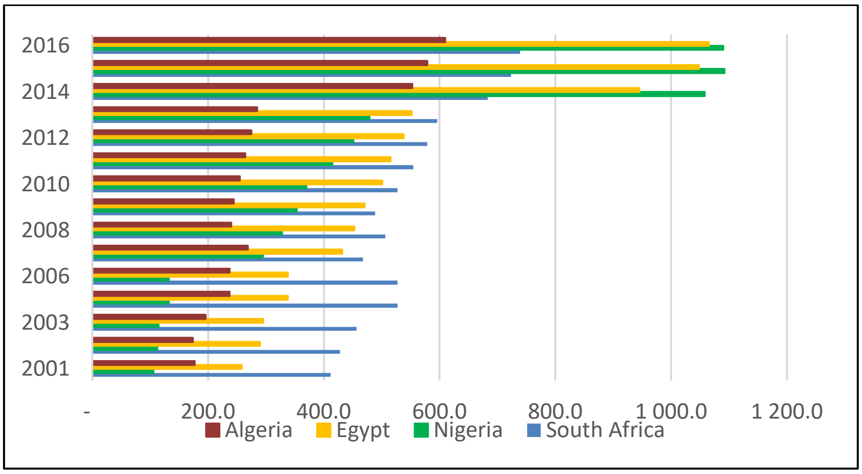

Figure 4.9: GDP in billions of USD for Africa

Neither the penetration nor the density metrics accurately reflect the size of the insurance market and do not produce information on a granular level to illustrate what each person actually spends on insurance, what the quality of the insurance coverage is or what customer satisfaction is. The metrics are handy, though, to compare respective markets to each other. The penetration is expressed as a percentage of the insurance premiums spent in relation to the GDP. In contrast, the density is expressed in a monetary value derived from insurance premiums spent in relation to the population. The penetration, therefore, demonstrates the state of a country's insurance development, and the density indicates how much each of the people in a country spends on insurance annually.

Figure 4.10 demonstrates the penetration and the density of the markets for the G7 countries. For the period 2001 to 2016, the penetration for the G7 countries on average for the USA market is 4,64% that fluctuated between 4,25% and 5,50%; that of the UK is 4,83% that fluctuated between 3,75% and 6,01%; that of Canada is 4,20% that fluctuated between 2,78% and 4,97%; that of Germany is 3,98% that fluctuated between 2,96% and 4,60%; that of France is 3,74% that fluctuated between 2,55% and 4,44%; that of Italy is 2,65% that fluctuated between 1,72% and 3,31% and that of Japan is 2,54% that fluctuated between 2,19% and 2,98%.

Over the period from 2001 to 2016, the density for the G7 countries for the US market on average was $2,138.98 and varied from $1,641.73 to

$2,455.80, that of the UK on average $1,633.53 with a variance from $1,098.46 to $1,818.95; that of Germany on average $1,408.90 with a variance from $817.41 to $1,681.18; that of Canada on average $1,617.27 with a variance from $763.02 to $2,102.35; that of France on average $1,228.49 with a variance from $643.33 to $1,498.67; that of Japan on average $847.88 with a variance from $701.83 to $1,026.48 and that of Italy on average $789.43 with a variance from $476.58 to $998.96.

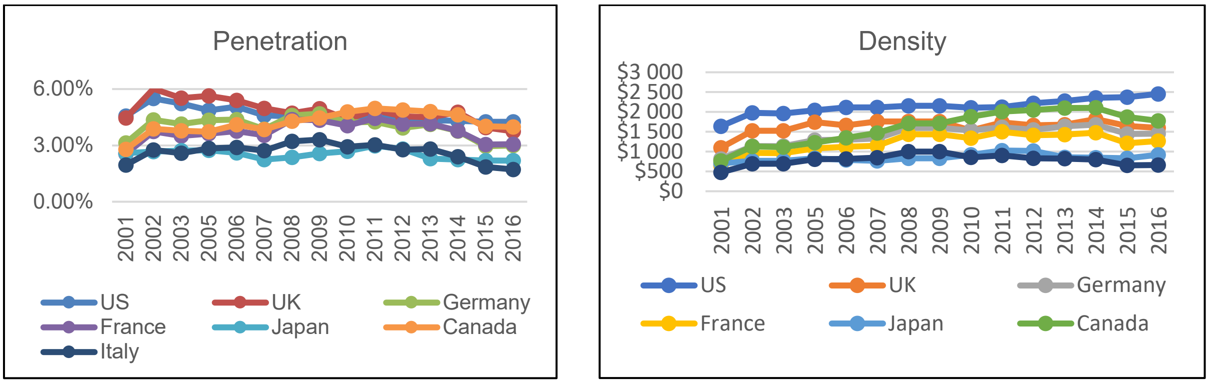

Figure 4.10: Insurance Penetration and Density of G7

Figure 4.11 demonstrates the penetration and the density of the markets for the BRICS countries. Over the period from 2001 to 2016 the penetration for the BRICS countries on average for South Africa is 1,41% that fluctuated between 0,76% and 1,95%; that of Brazil is 1,09% that fluctuated between 0,60% and 1,63%; that of Russia is 1,01% that fluctuated between 0,39% and 1,83%; that of China is 0,57% that fluctuated between 0,18% and 0,95% and that of India 0,19% that fluctuated between 0,10% and 0,28%.

Over the period from 2001 to 2016 the density for the BRICS countries for the South African market on average is $161.62 and varies from $72.05 to $222.12, that of Russia on average $157.97 with a variance from $32.33 to $304.68; that of Egypt on average $9.00 with a variance from $5.07 to $12.66 and that of Nigeria on average $5.24 with a variance from $1.66 to $7.94.

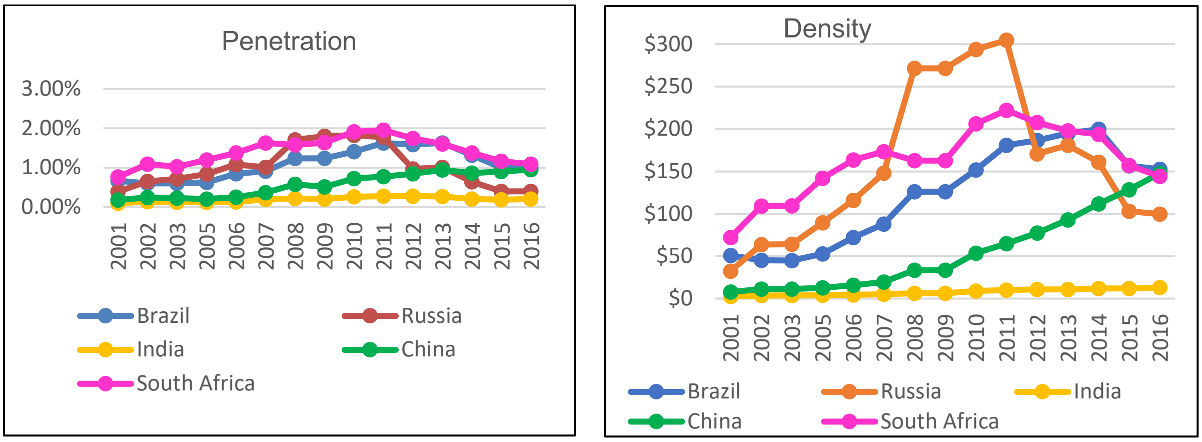

Figure 4.11: Insurance Penetration and Density of BRICS

Figure 4.12 demonstrates the market penetration and density for the African countries. Over the period from 2001 to 2016 the penetration for the African countries on average for South Africa is 1,41%, fluctuating between 0,76% and 1,95%; that of Algeria is 0,29%, fluctuating between 0,15% and 0,47%; that of Nigeria is 0,25% that fluctuated between 0,07% and 0,37%, and that of Egypt is 0,15% fluctuating between 0,10% and 0,19%.

Over the period from 2001 to 2016 the density for the African countries for the South African market on average is $161.62 and varies from $72.05 to

$222.12, that of Algeria on average $23.84 with a variance from $8.43 to $38.44; that of Egypt on average $9.00 with a variance from $5.07 to $12.66 and that of Nigeria on average $5.24 with a variance from $1.66 to $7.94.

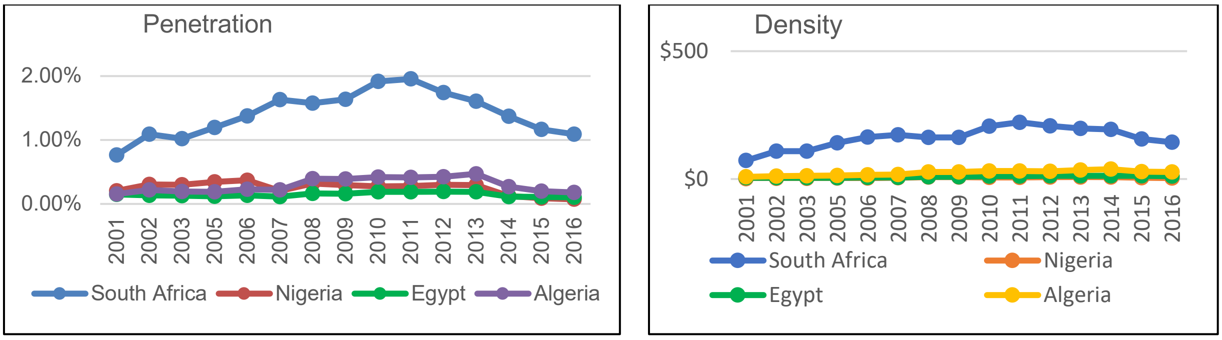

Figure 4.12: Insurance Penetration and Density of Africa

4.4 THE SIZE OF THE SOUTH AFRICAN NON-LIFE INSURANCE MARKETS COMPARED TO G7, BRICS AND AFRICAN COUNTRIES

It is evident from the analyses above that the South African insurance market punches well above its weight when the size of its economy, population and performance of its insurance industry are considered. The comparison between the countries considered, as set out in Table 4.3, further illustrates the fact.

Table 4.3: Comparison of the South African non-life insurance market's performance with G7, BRICS and African countries

Countries	Metrics of other countries relative to South Africa				
	Size of economy	Population	Premiums	Penetration	Density
G7:					
USA	X 25.20	X 5.78	X 98.74	X 3.29	X 13.23
UK	X 3.78	X 1.17	X 13.05	X 3.42	X 10.11
Canada	X 2.19	X 0.65	X 9.21	X 2.98	X 10.01
Germany	X 5.45	X 1.48	X 14.97	X 2.83	X 8.72
France	X 3.74	X 1.20	X 10.55	X 2.65	X 7.60
Japan	X 7.25	X 2.27	X 14.58	X 1.79	X 5.25
Italy	X 3.15	X 1.08	X 4.97	X 1.88	X 4.88
BRICS:					
Brazil	X 4.25	X 3.71	X 3.95	X 0.77	X 0.75
Russia	X 4.92	X 2.58	X 1.70	X 0.72	X 0.98
India	X 11.77	X 23.68	X 2.18	X 0.14	X 0.05
China	X 28.96	X 24.66	X 25.32	X 0.40	X 0.34
African:					
Algeria	X 0.82	X 0.73	X 7.60	X 0.21	X 0.15
Egypt	X 1.44	X 1.71	X 7.60	X 0.10	X 0.06
Nigeria	X 1.47	X 3.33	X 9.50	X 0.18	X 0.03

Source: Author's own

Italy, the smallest economy of the G7 countries, with an economy that is 3.15 times larger and a population that is 1.08 times larger than that of South Africa, has an insurance industry that is only 1.88 times more developed than that of South Africa. Japan, with an economy that is 7.25 times larger and a population that is 2.27 times larger than South Africa, has an insurance industry that is only 1.79 times more developed than South Africa.

Even though China has an economy of 28.96 times larger and a population of 24.66 times larger than South Africa's, its insurance industry only performs at 40% of South Africa's. Similarly, India has an economy that is 11.77 times larger and a population that is 23.68 times the size of South Africa's. Its insurance industry only performs at 14% of South Africa's. The performance of the other African countries, Algeria, Egypt and Nigeria, is similar to that of India at 21%, 10% and 18%, respectively, of South Africa's performance.

The South African insurance industry's performance thus resembles that of developed countries rather than that of the other developing countries analysed.

Despite the South African insurance industry's high level of development, there is still much room for improvement. It is a common cause that the South African economy is one of the most unequal globally. As the citizens progress in building their wealth, obtaining their own property becomes a priority. Due to the legacy of South Africa's previous political dispensation, there is an inordinate number of first-time homeowners who would need guidance on issues related to their new home, particularly how they need to protect their financial position against possible unforeseen events.

4.5 THE LARGEST BUSINESS CLASSES WITHIN THE NON-LIFE INSURANCE

The largest business classes in non-life insurance are the motor class, followed by the property class. In the South African context, the average ratios of direct premiums written for the years 2013 to 2016 are 44% for motor insurance and 32% for property insurance, and the other six classes share the balance of 23%.

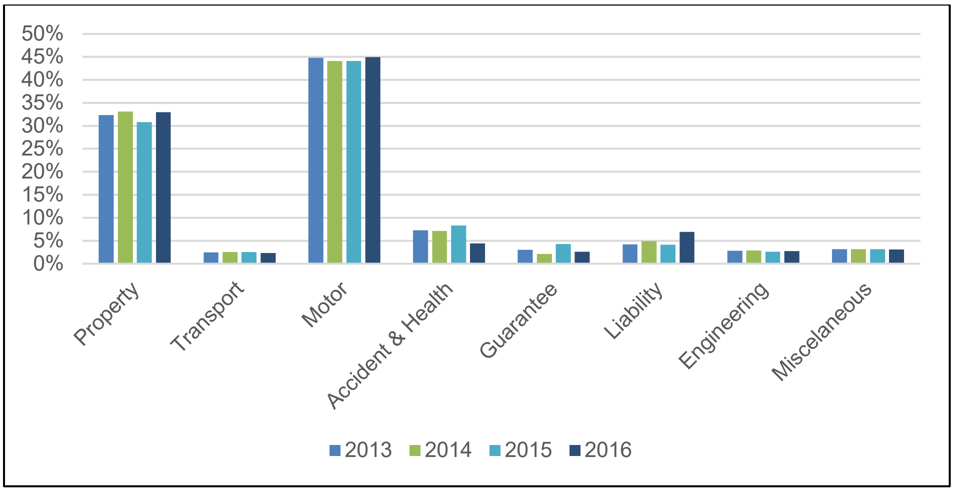

Figure 4.13: Split of South African short-term insurance business classes (Derived from Financial Services Board Insurance Division, 2013 to 2016)

The share of motor and property insurance premiums for insurance markets in other countries over the same period compared to South Africa is set out in Table 4.4.

Table 4.4: Comparison of motor and property premium share

Countries	Motor premiums as % of total premiums	Property premiums as % of total premiums	Balance for all other business classes
South Africa	44%	32%	23%
Canada	31%	25%	43%
France	27%	25%	48%
Germany	23%	19%	58%
Italy	53%	16%	32%
Japan	57%	18%	25%
UK	22%	27%	51%
USA	20%	12%	68%

Source: Derived from OEDC (2024).

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There is no consistency in the contribution of the property class to the total premiums written for the G7 countries compared to South Africa's, as illustrated in Table 4.4. Similar granular information is not available for the BRICS and African countries. Therefore, the total premiums written were used to compare the market penetration and density of the different countries to each other in the preceding section.

The larger share of motor insurance indicates a higher risk profile than that of property insurance. Property insurance's risk profile is described as a low-probability-high-consequence risk.

4.6 A VIEW OF PROPERTY INSURANCE'S RISK PROFILE

The H W Heinrich's triangle, devised in 1931, was based on the occurrence of insurance claims for workplace accidents. Thoyts (2010) maintains that the principles apply equally to many applications and property insurance. The tendency shows that the risk frequency is inversely proportional to its severity, as illustrated in Figure 4.14. The premise is thus that many more trivial events will occur before a catastrophic event does.

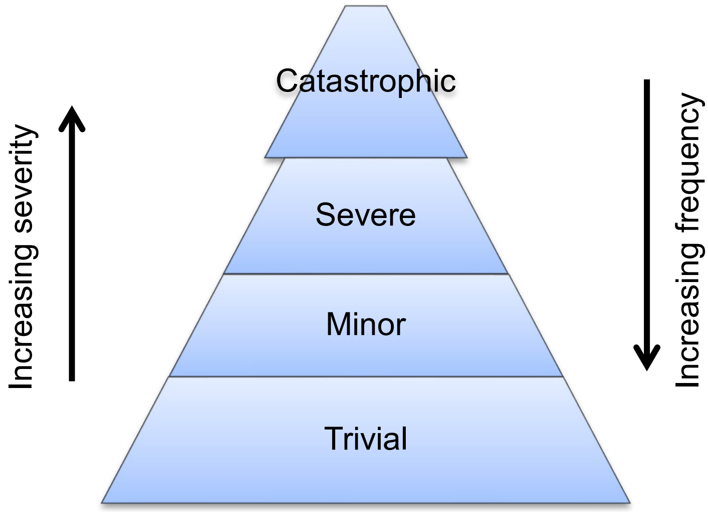

Figure 4.14: The Heinrich triangle (Thoyts, 2010)

Due to the considerable value of residential properties, most damage to them could be regarded as severe when weighing the homeowners' financial cash flow against the repair cost.

The theory behind the supply and demand benchmark models for insurance sheds light on assumed information deemed available to both parties when assessing their exposure to risk and deciding on the appropriate measures to be taken.

The supply benchmark model assumes insurers maximise the profit for their shareholders in a competitive insurance market. This means that different insurers can charge different premiums for the chosen coverage. The model further assumes that insureds are fully informed about the likelihood of risks occurring and their consequences so that the appropriate amounts of insurance can be purchased to maximise their expected utility.

The demand benchmark model assumes insureds maximise their expected utility. This means that risk-averse individuals are prepared to pay premiums exceeding their expected losses. For example, where the insured amount is R3,500,000, and the probability of a loss occurring is 1%, the expected loss is R35,000. The insured should thus be prepared to pay any amount above R35,000 to transfer the risk to the insurer (Kunreuther *et al.,* 2013).

Any deviation from the assumptions the benchmark models are based on would thus result in anomalies. The demand side anomaly under investigation in this research is the failure of individuals to maximise their expected utility. The supply-side anomaly is that well-defined probabilities and outcomes associated with the risk related to their residential properties are often lacking.

Evidence that decision-making with regard to purchasing low-probability-high-consequence insurance does not follow economic models of rationality has motivated several academics to lean towards behavioural economics to gain an understanding of what motivates decision-making when purchasing insurance for low-probability-high-consequence risks (Kunreuther *et al.,* 2013*).*

Hogarth and Kunreuther (1995) experimented to determine how decision-making would change when knowledge levels pertaining to probabilities and outcomes changed. The conceptual differences in the decision-making process are simulated in the experiment where the probabilities, as well as the outcomes, are either known (precise), unsure (ambiguous or risky) or unknown (ignorance), as illustrated in Figure 4.15. It was established through the simulated situations for precise-precise and ignorance-ignorance scenarios that people made different decisions under risk than under ignorance.

Knowledge:

Probabilities

Loss

	Precise	Ambiguous	Ignorance
Precise	Precise-Precise	Precise-Ambiguous	Precise-Ignorance
Ambiguous	Ambiguous-Precise	Ambiguous-Ambiguous	Ambiguous-Ignorance
Ignorance	Ignorance-Precise	Ignorance-Ambiguous	Ignorance-Ignorance

Figure 4.15: Characterisation of decision-making situations
Source: Hogarth and Kunreuther (1995)

The precise-precise and precise-ambiguous scenarios are common cases in insurance, such as motor insurance, where the probability of damage occurring is well known, and the consequences or outcomes can be fairly accurately estimated from historical data. Building insurance falls into the category of ambiguity-ambiguity, where there is disagreement amongst experts regarding the probability of an event, such as a fire, severe hailstorm, and so on, occurring. The severity of the loss is also not accurately determinable and is indicated by a range of values rather than a single value (Hogarth & Kunreuther, 1995).

A study exploring how people respond to information pertaining to low-probability-high-consequence events and what is required to increase individuals' sensitivity to the likelihood that these events would occur revealed that the public needs substantially more contextual information to be able to appropriately respond to low-probability-high-consequence risks as what insurers provide (Kunreuther *et al.,* 2001*).*

Experiments were also conducted to determine the effects of specific states of mind, such as worry, regret, and disappointment, on decision-making about purchasing low-probability, high-consequence insurance.

One such experiment testing the influence of worry established that the willingness to pay for low-probability-high-consequence insurance is higher when the probability is ambiguous and that there is a positive correlation between the willingness to pay and the level of worry. Thus, the more worried individuals are about incurring a loss, the higher their willingness to pay for insurance. It was also established that the worry factor is statistically much more significant than the availability of known probabilities (Schade *et al.,* 2012).

All the research by Kunreuther *et al.* (2001, 2013), Hogarth and Kunreuther (1995) and Schade *et al.* (2012) pertained to decision-making regarding the price individuals are prepared to pay for low-probability-high-consequence risks. Although no consideration was given to the determination of the sum to be insured in this research, the fact that the insureds displayed decision-making principles commensurate with behavioural economics rather than principles commensurate with rational economics is significant, as it indicates the insecurity in the decision-making related to the probability, the consequence of a possible loss as well as the limit of the indemnification (sum insured) required to cover at the event of total loss.

4.7 DETERMINING THE CORRECT INSURANCE VALUE

The most important essential of insurance, as stated in Chapter three, is the principle of indemnity that is supported by the undertaking by the insurer to compensate the insured, the determination of the risk and the transfer thereof, the consideration of the common pool where the policy is placed and the determination of the premium. The process of establishing the insurance contract should be conducted in such a manner that over-insurance and under-insurance are avoided. When called upon, the indemnity is executed according to any one of four methods: the replacement or reinstatement of damaged goods, the repair of damaged goods or monetary compensation.

4.7.1 Methods to execute indemnity

The methods of executing indemnity for insurance that cut across all sectors of the economy are relatively straightforward, as the replacement or reinstatement value of most commodities is the same as the market value thereof. Replacing general possessions would involve obtaining quotations from retail outlets, submitting those to the insurer and being compensated accordingly.

The situation is very different for the built environment because the replacement and / or reinstatement cost of a building is very different from its market value. The determination of the replacement and / or reinstatement cost is associated with techniques and services rendered by quantity surveyors, whereas the determination of the market value is associated with the techniques and services rendered by valuers. It is thus apparent that quantity surveying and valuation are two distinctly different professions that follow vastly different techniques in determining cost or value.

The insurance industry has bounced between the two different techniques over time. As alluded to previously, the USA insurance market profoundly influences the global insurance market merely due to its size. The USA market has taken the lead in several developmental aspects related to the insurance industry and has implemented various methods for determining replacement costs.

4.7.2 The under-insurance situation

The positions of over-insurance and under-insurance and the specific importance and consequences of under-insurance in the context of this research were highlighted in the previous chapter. The importance of under-insurance is emphasised by Kunreuther *et al.* (2013), that maintaining the purchasing insurance at a slightly higher rate or even purchasing excessive coverage is unlikely to be as detrimental to an individual's financial situation as no insurance or under-insurance would be. Determining the correct value for insurance purposes is thus of paramount importance, as it is the value that informs the premium or price and, therefore, also the value of indemnity.

When considering the situation of under-insurance of property globally, a distinction must be made between under-insurance as a result of the risk of extreme natural disasters such as earthquakes, hurricanes and floods and under-insurance as a result of the risks of general perils such as fire, burglary, water damage and the like. According to Swiss Re Sigma (2015), the under-insurance for natural disaster risk globally is around 70%. Although South Africa has low exposure to natural hazards, it is not totally free of them, as floods, storms and wildfires occur regularly. There are also frequent earthquakes in South Africa that are mainly related to mine activities and thus do not damage infrastructure and buildings on the earth's surface.

The under-insurance for general perils in developed countries is mainly due to the insurability of undervaluation, and in developing countries, the cause is instead the slow uptake of insurance (Swiss Re Sigma, 2015). The extent of under-insurance for general perils is difficult to determine as insurance systems do not capture the uninsured losses. The opening remark on Santam, South Africa's largest insurer, building calculator, indicates, ""Did you know that approximately one out of three South African homes is currently under-insured by at least 30%?"

There are different forms of under-insurance. These are uninsured insured, but certain perils are not covered insured, but the policy contains restrictions and is insured but undervalued (Swiss Re Sigma, 2015). The latter is the focus of this research.

4.7.3 Replacement and reinstatement

Understanding the terminology is crucial to the method of determining the insured value. Replacement cost refers to replacing the damaged building at current construction costs, according to current building regulations, to the same level of efficiency and quality as before the damage, by utilising modern materials. Reinstatement refers to the exact reproduction of the building at current construction costs, a replica of the design, materials and workmanship. This is often also referred to as reproduction cost.

4.8 USE OF COST DATA FROM THIRD PARTIES

For a long time, insurers have prided their success on the use and quality of their data. They continually review the data to improve their competitive advantage in pricing above each other. According to Evans (2015), the insurance industry stakeholders are discussing data because the industry finds itself amidst a paradigm shift, the data revolution, and depending on how the industry responds to the challenge will determine the future of the industry as access to and analysis of data will not remain unique with insurers.

The success in using the data is identifying what data sets will enhance the understanding of risks better and are suited for incorporation into the underwriting process. Insurers purchase data from external sources based on the coverage, granularity, quality, accuracy, scalability and value-adding capability to improve their underwriting results. Insurers are keen to purchase data that will improve their understanding of building attributes, provided the quality and accuracy of the data are proven (Murray, 2019). Research into establishing what external data is used or intended to be used within the near future, it was found that 99% of insurers used flood data, 82% used theft data, 81% used modelling tools, 78% used storm and subsidence data, 70% used fire data and mapping tools, 59% used building reinstatement costs and building attributes, 52% used escape from water data, 49% used lifestyle data, 48% used accidental damage and 40% used freeze data (Insurance Post and Verisk, 2019). What was revealing about these statistics is that insurers are not necessarily obtaining the correct kind of information. The 82% use of theft data analysed down to a neighbourhood or even a specific street address would not yield the same benefit as analysing building reinstatement and attributes to the same level of granularity, yet only 33% of insurers are analysing the building data at the neighbourhood level and only 25% to specific street address granularity (Insurance Post and Verisk, 2019). The building reinstatement and attributes of these external data sets are the pinnacles of this research. The uptake of third-party software to determine building replacement costs might be high in some global centres but has limited uptake in South Africa.

According to the RICS (2018b), data that have formed part of quantity surveyors' expertise for many years is increasingly moving into the public domain. The data have become machine-searchable, and the information previously calculated by professionals is now generated by machine-learning algorithms. These techniques are required to develop and advance data sets for testing. However, private practices are reluctant to share their data sets;

thus, there is no real progress in machine-learning techniques (RICS, 2018b).

The insurance industry and the built environment are renowned for their slow technology adoption. In the case of the built environment, the slow uptake is frequently attributed to the fragmented nature and diverse stakeholders involved in the built environment's supply chain.

4.9 THE CURRENT INSURANCE OPERATIONAL MODEL AND FUTURE TRENDS

The operational insurance model is predominantly linear, where information moves in one direction through the value chain with little interaction between the different silos. As illustrated in Figure 4.16, this model is still followed by most insurance companies. The global lockdowns caused by the Coronavirus disease 2019 (COVID-19) pandemic have highlighted the need for digitisation and a seamless customer experience across all the silos. Each silo is, to a larger or lesser extent, reliant on partnerships or third-party administrators for their execution and performance. For instance, sales and distribution rely heavily on agents, brokers, and direct and indirect digital distribution channels (such as banks). Claims management also relies heavily on third-party administrators who manage the claims and handling costs. Products, underwriting, sales, and administration are less reliant on partners. The technology that is, in most cases, based on in-house developed legacy systems poses a compatibility problem with new digital development mostly performed by partners (Bisbjerg, 2020).

<table>
<tr><td>Products and Underwriting</td><td>Sales and Distribution</td><td>Service and Policy Administration</td><td>Claims Management</td></tr>
<tr><td colspan="4">Company Infrastructure</td></tr>
<tr><td colspan="4">Technology Architecture</td></tr>
</table>

Figure 4.16: Traditional insurance value chain
Source: Bisbjerg (2020)

Insurtechs, technological developments specifically for the insurance industry, have started to influence the traditional insurance value chain through innovative initiatives in some parts of the value chain. The percentage influence that Insurtechs have had on the different functions in the traditional insurance value chain are shown in Figure 4.17. Evidently, there is less focus on the pricing and underwriting function and even less focus on the claims management function.

<table>
<tr><td></td><td></td><td>19%</td><td colspan="2">45%</td><td>28%</td><td>8%</td></tr>
<tr><td>Marketing</td><td>Product Development</td><td>Pricing and Underwriting</td><td>Sales and Distribution</td><td>Policy Issuance</td><td>Policy Servicing</td><td>Claims Management</td></tr>
</table>

Figure 4.17: Insurance value chain
Source: Bisbjerg (2020)

The Insurtechs are improving the efficiency of their functions but are not disrupting the current operational models. Bisbjerg (2020) opines that the ways that man and machine are combining has never been seen or imagined before, fuelled by the Fourth Industrial Revolution that was first described in 2016 and further accelerated by the COVID-19 pandemic, compels insurers to change with its globally connected changing environment if it hopes to remain relevant in future. Bisbjerg (2020) further states that fixed costs and workforce rigidity are the two most significant factors restricting insurers from being flexible and acting quickly to internal and external perilous events. The rigidity is most evident in insurers' siloed organisations, where the silos operate independently with limited interaction. Yet, flexibility and agility are exactly what is required in a customer-centric world with its fluctuating demand and price indexes. Customers are increasingly demanding a seamless digital experience throughout the value chain. Insurers currently offer digital sales and some administrative functions but do not extend to claims management.

Two major trends that will drive and change the insurance industry are individuality and the need for immediate coverage and only what is needed. Customers express their needs through product choices, expect custom-made products, and expect these products to be delivered immediately and only what is needed, for example, as-you-use applications. Both these trends require technological advancements such as artificial intelligence and Internet of Things (IoT) applications to combine services and products (Bisbjerg, 2020).

The focus of this research is on the development of a model to serve as support for and improve the underwriting of residential buildings. However, the model could also serve the claims management function. The claims process is the moment of truth for the insured and the insurer alike, as this is where the effectiveness and efficiency of the purchased insurance becomes apparent. It is when the adequacy of the insured sum is tested, and the insured is faced with the reality of whether the insured sum is adequate to restore the damaged building to the state it was in before the damage occurred. Insurers in South Africa offer little support to ensure the correct sum insured but employ several professional services to inform the claims process.

4.10 SUMMARY

The economic importance and the size of the non-life South African insurance market were highlighted in the chapter. The performance of the South African market was also compared to the G7 countries and the BRICS countries to establish how the South African market compares globally, and it is evident that the South African market outperforms its BRICS peers and compares somewhat favourably with the European market. Despite the good performance of the South African market, there is much room for improvement, as pointed out by the low penetration rate.

An overview of the supply and demand benchmark models revealed that deviations from the theoretical assumptions that insurers deem available to insureds when deciding on purchasing insurance for low-probability-high-risks insurance lead to commensurate decision-making with behavioural economics rather than rational economics. This indicates that insureds need much more information to inform their decision-making.

Understanding the difference between replacement and reinstatement costs as methods of executing indemnity for damage to residential buildings and the persistence of underinsurance is stressed.

Lastly, the use of third-party data to enhance insurers’ ability to assess risk better is discussed. This includes data to address building attributes for assessing replacement and / or reinstatement costs. The pressure on insurers to embrace technology is evident from the discussion on current operational models of insurance companies to meet the customer-centric need for individualised products.

CHAPTER 5: THE BUILT AND QUANTITY SURVEYING COST ENVIRONMENT

5.1 INTRODUCTION

The preceding chapter outlined the linkage between the insurance environment and the built environment, specifically the insurance of residential properties. This chapter considers the built environment, emphasising the generation of building costs for residential properties. Klein (2018) states that writing about insurance, construction, and economics is challenging, because very little information is available in the public domain for these disciplines. He continues by saying that most USA homeowners do not have adequate homeowners' insurance and do not know it. He further opines that insurers' systems to determine replacement costs lead to unintended under-insurance. The key to solving the ongoing situation of unintended under-insurance lies in understanding how the estimating systems work. He confirms that understanding the estimating systems is largely ignored by academics and the insurance industry (Klein, 2018).

As alluded to previously, the sheer size of the USA insurance market causes it to have a significant influence on how insurance companies globally conduct their business. Therefore, the scenario of unintended under-insurance sketched by Klein (2018) above also occurs globally. This is particularly relevant in South Africa due to the extraordinary number of first-time homeowners caused by urbanisation and the changed political dispensation. After the abolition of apartheid laws that restricted land ownership on 30 June 1991, black, Indian and coloured South Africans were permitted to own land. Urbanisation increased from 45,6% in 1991 to 53,4% in 1996. That is a 7,8% increase over the period when South Africa transitioned to a democracy and further increased by 10,7% to 64,1% in 2011 (Baffi *et al*., 2018).

5.2 PROCUREMENT IN THE BUILT ENVIRONMENT

Procurement systems lie at the heart of the estimating systems that Klein (2018) refers to. Generally, procurement is defined as the process of obtaining goods or services from another party. In the built environment, however, it is seen as the establishment, management, maintenance and fulfilment of construction contracts. It is an integral part of the building process through all project phases whenever external resources such as plant, materials, services and the like are required (CIDB, 2007). Hackett and Statham (2016) opine that the degree of complexity of procuring building contracts lies, amongst other aspects, in achieving value for money, regulating complicated relationships, demonstrating accountability, involving professional consultants and adhering to numerous regulations. Regardless of the complexity of the project inputs, all projects rely on relatively simple established principles for dealing with the project's primary objectives of cost, quality and time. The weighting allocated to each parameter demonstrates the client's preference and goal in creating the building.

The built environment relies on input from two distinct groupings for the successful execution of a building project. These two groupings are the design team and the contractor, where the client contracts each design team member and the contractor. The design team constitutes all the professional consultants required for a building project. The more complex the design, the more consultants will be involved. An essential design team would include an architect, engineers (civil, structural, electrical, mechanical, and the like) and a quantity surveyor (also referred to as a cost consultant or cost engineer). The construction team would constitute a main contractor, several subcontractors and specialist suppliers. Again, the more complex the design and execution of the construction are, the more specialist subcontractors and suppliers would be involved. A typical procurement cycle for a building project in South Africa follows the steps of determining what is to be procured, deciding on the procurement strategy, obtaining tenders for the construction of the building, evaluating the tender offers, awarding the contract and administering the contract (CIDB, 2007). This cycle is similar to what happens globally. Residential buildings are regarded as relatively simple structures. Therefore, extended professional teams are seldom involved in the procurement thereof. Often, only the design consultants and the contractor are involved, and the contractor then assumes the quantity surveying or cost control functions.

Procurement strategies revolve around two aspects: the conditions of the contract that determine the roles, responsibilities, and liabilities of the contracting parties and the price determination method through which the contractor's services are obtained (Jaggar & Morton, 1995).

The price determination methods are at the heart of this research, forming the basis for the proposed cost model. Therefore, it is essential to discuss the decision-making that would influence the initial cost of a building. This initial cost does not affect the replacement cost for existing buildings. Still, the principles behind the different costing methods and their application at various stages throughout the procurement cycle are crucial to understanding the appropriateness of their application.

The procurement strategy thus significantly influences the success of a building project. The building owners' (also referred to as the client or employer in the built environment) objectives regarding the three primary goals of time, cost and quality are required for all projects. The end-use of the building must, therefore, be understood at an early stage of the building's planning (Brandon, 1992). Procurement strategies are broadly divided into two categories: traditional and non-traditional. The roles of the designers and contractors determine the division between these two categories. With the traditional strategy, the design responsibility remains with the client and their appointed design consultants, whereas with non-traditional strategies, the contractor is involved in the design. Non-traditional strategies have been developed to address the shortcomings of the traditional strategies. The strategies are, however, not mutually exclusive and are often applied in combination depending on what the project at hand requires (Ashworth, 1996). The procurement strategies commonly practised in commonwealth countries, including South Africa, are identified as:

- Lump-Sum or Fixed-Price Contracts, where the cost is evaluated on predetermined costs such as rates.
- Cost-reimbursement contracts that are based on actual costs for the material, labour, plant and execution and the contractor's overheads and profit are a determined percentage.
- Design and Build Contracts, where one entity takes on the design and execution responsibilities of the project and carries all the liability.
- Package Deal Contracts are standardised design and build options where the building is chosen from the manufacturer's catalogue.
- Turnkey Contracts entail delivering a building ready for occupation and prepared for use, including furniture, fixtures and equipment.
- Continuity Contracts that aim to reduce tendering costs and expedite execution where economies of scale are at play.
- Integrated management Contracts are where the contractor's expertise is employed in the design and execution stages, and the contractor is compensated on a percentage basis for managing the construction works.

- Separate/Divided Contracts entail the architect designing and managing the execution of the project on behalf of the client and arranging separate contract packages for different contractors.
- Partnering Contracts aim to circumvent barriers between clients and contractors caused by traditional contracting relationships and strengthen mutual objectives, trust and sharing of risks and rewards (Hackett *et al.,* 2007, 2016; Kirkham, 2007,2014).

In the USA, three procurement strategies, or project delivery methods, are recognised, namely the

- Design-Bid-Build (DBB) (also referred to as the traditional method).
- Design-Build (DB).
- Construction Management (CM) (The National Academies of Science, Engineering and Medicine, 2009).

These strategies are aligned to the Lump-Sum or Fixed Price Contracts, Design and Build Contracts and Integrated Management Contracts as discussed above.

The traditional procurement methods of the Fixed Price Contract or Design-Bid-Build remain the most prevalent procurement strategies (Hackett *et al.,* 2007, 2016; The National Academies of Science, Engineering and Medicine, 2009). Fixed price items are defined as "… items paid for based on a predetermined estimate of the cost of the work, including an allowance for the risk involved and the market situation in relation to the contractor's workload". The price determination methods best suited for fixed price strategies are either bills of quantities, provisional bills of quantities or schedules of rates. The fixed price can, therefore, be either a unit rate for a specific measured item, a section of the work, or the complete contract. The contract can thus consist of a multiplicity of unit rates, a series of trades or elements or a single lump sum (Hackett *et al.* 2007, 2016). Kirkham (2014) concurs with Hackett *et al.* (2007, 2016), that the lump-sum contract in its various forms, with firm or approximate bills of quantities, quantities or approximate quantities, remains the most widely used contract. The alternative forms of contract developed to overcome the shortcomings of the lump-sum or fixed-price contract are primarily driven by sophisticated clients regularly developing complex commercial projects. For owners of smaller, more straightforward and probably once-off developments, and hence much less experienced in procurement processes, the safer option thus remains the traditional procurement with detailed price determination documents.

5.3 TRADITIONAL BUILDING COST MODELLING

Two schools of thought exist for building cost modelling. The first is product-based modelling, and the second is process or resource-based modelling. Product-based modelling presents the costs of the complete product or building and thus represents what is to be built. In contrast, resource-based modelling provides for the costing to be based on the actual resources employed in the construction process and thus represents how the building is to be built (Skitmore & Marston, 1999; Kirkham, 2007,2004; Jagger *et al*., 2002; Greenhalgh, 2013; Lawther & Edwards, 2001).

Ashworth and Perera (2015) see these traditional models as models of cost because modern cost modelling, facilitated by computer technology, are statistical and operational research techniques for forecasting construction costs. However, there is little evidence that these techniques are superior to the models of cost still in use and, therefore, not adopted in a large scale in practice.

For a cost model to achieve its objectives,

- its refinement must be aligned with the design stage of the buildings.
- It must be possible to update the model.
- The cost representation must be aligned to the building components as closely as possible to the cost occurrence during the production process.
- It must be possible to test the design constraints for feasibility.
- The model's results should enable the knowledge to be incorporated into drawings, specifications, and quantities to form part of the decision-making process (Kirkham, 2007, 2014).

The need for early design cost advice drove the purpose of developing and refining design cost models. Proponents of resource-based costing models concede that a lack of data prohibits using this method for early cost advice. Another criticism is that consultants lack an understanding of the construction process and are, therefore, unable to apply the model (Skitmore & Marston, 1999; Lawther & Edwards, 2001). The resource-based models have thus not gained any traction in practice. The product-based cost models developed for implementation at various design stages are as follows:

Table 5.1: **Design stage and its relationship to cost modelling**

Design stage	Drawing development	Cost model	User
Feasibility	Sketch plans	Unit / function cost, cost/m^2	QS
Scheme design	Sketch plans	Elemental costs	QS
Detailed design	Sketch plans Working drawings	Standard method of measurement. Approximate quantities	QS
Detailed design	Working drawings	Standard method of measurement. Detailed quantities	QS
Execution	Working drawings	Operations programme related	Contractor
Execution	Working drawings	Resources programme related	Contractor

Source: Derived from Kirkham (2007, 2014); Jagger *et al*. (2002).

The intention of the cost models is evident. The further the design is developed, the more detailed design information is available, and the more detailed the cost model becomes.

5.3.1 Unit / functional cost models

The unit / functional cost model, also called a single price rate method, entails applying a unit cost to the number of units; for example, a parking garage, which would be the number of parking bays multiplied by the cost of a bay; a hospital, which would be a hospital bed multiplied by the cost per bed; a school which would be pupil multiplied by the cost per pupil (Jagger *et al.*, 2002; Kirkham, 2007; Ashworth & Perera, 2015).

5.3.2 Superficial area cost models (Cost / m^2)

This method entails calculating and multiplying the total building area by a rate per square metre. Defining the building area is important, as various global standards differ in their approach. Some prescribe gross external floor area (GEFA), and others gross internal floor area (GIFA) (ICMSC, 2021). The difference between the two measures is, therefore, the structure area. The South African standard prescribes GEFA (ASAQS, 2016).

This method is still widely used for early-stage estimating.

5.3.3 Elemental cost models

An element is defined as a significant part of a building that always performs the same function regardless of its construction or specification, such as the substructure element that could comprise strip foundations, raft foundations or piles. Similarly, the roof element could be double-pitched timber trusses with concrete roof tiles, or a flat waterproofed concrete roof (ASAQS, 2016; Kirkham, 2007, 2014).

This model has achieved the best design cost planning for early cost advice (Kirkham, 2007, 2014).

5.3.4 Standard method of measurement cost models

The discussion on procurement strategies highlighted the importance of how the costs of projects are determined, and bills of quantities and provisional bills of quantities are mentioned frequently as tools to accomplish this. These bills of quantities are thus nothing other than cost models that symbolically represent the building components in their designed form through the suitable quantities to be priced by tenderers or contractors and combined form the cost model (Kirkham, 2007, 2014). Kirkham (2007, 2014) describes the objectives of modelling as giving clients economic assurance in the form of the expected project cost, allowing quick development of the cost representation of the building that can be tested and analysed, and establishing a system that informs the designer on the costs compatible with the design. It creates a link between cost control of the design relative to the expenditure of resources on site.

The popularity of the bill of quantities as a cost modelling tool lies in its simplicity in effectively communicating through the description of finished work and its associated quantity to other parties, such as tendering contractors, subcontractors and the like, what work and how much of it is required to be done (Jagger *et al*., 2002). Regardless of this popularity, bills of quantities have come under severe criticism for their perceived inaccurate modelling and inability to truly reflect construction management costs and the employed resources (Jagger *et al*., 2002).

5.4 ACCURACY OF COST MODELS

The International Association for the Advancement of Cost Engineering's (AACE) (2020) recommended practice notice No. 56R-08 as applied in Engineering, Procurement and Construction for the Building and General Construction Industries sets out a cost estimate classification system that indicates five classes of estimates aligned to the project definition maturity level, estimating methods and expected accuracy range for each. The expected accuracy range in the classification system indicates the general relationship between the project definition level and the estimate accuracy. This research is based on the most accurate information that exists for the project, which will never increase and hence is regarded as 100% accurate; therefore, the percentages are regarded as estimated accuracy. The descriptions in the class estimation system are aligned with the design development cost models and are shown in Table 5.2.

Table 5.2: Cost estimate classification system

Class	Estimating method	Comparison	Expected accuracy range (%)
1	Detailed unit cost with detailed take-off	Bill of quantities	Low: -3 to -5 High: +3 to +10
2	Detailed unit cost with forced detailed take-off	Provisional	Low: -5 to -10 High: +5 to +15
3	Semi-detailed unit cost with assembly level line items	Elemental estimate	Low: -5 to -15 High: +10 to +20
4	Parametric models, assembly driven models	R/m^2	Low: -10 to -20 High: +20 to +30
5	Parametric models, Judgement or Analogy	R/Unit	Low: -20 to -30 High: +30 to +50

Source: Derived from No. 56R-08 as applied in Engineering, Procurement and Construction for the Building and General Construction Industries, AACE (2020).

Lawther and Edwards (2001) compared research on estimate accuracy, as shown in Table 5.3.

Table 5.3: Estimate accuracy

	Researchers	Estimation stage	Accuracy
1	Ashworth and Skitmore (1983)	Design stage	± 20 to ± 40%
2	Ashworth and Skitmore (1983)	Pre-tender stage	± 10 to ± 15%
3	Flanagan and Norman (1983)	Pre-tender stage	± 10 to ± 25%
4	Beeston (1974)	Pre-tender stage	± 5 to ± 30%
5	Morrison (1984)	Pre-tender stage	12%

Source: Lawther and Edwards (2011).

The accuracy for the pre-tender stage estimates shown in Table 5.3 is closely aligned with the AACE accuracy range for the elemental estimate, as shown in Table 5.2. The comparison between design stage estimating and tenders remains awkward due to the state of flux of cost information during the design stage. Nevertheless, the accuracy ranges are the best indications available.

5.5 DESIGN FACTORS THAT INFLUENCE CONSTRUCTION COSTS

Several design factors influence the costs of buildings. Although the factors are known, the degree to which their changes influence costs is unknown due to a lack of research (Seeley, 1996; Kirkham, 2007, 2014; Ashworth & Parera, 2015).

5.5.1 Building size and planning efficiency

Building costs are not proportionate to building size changes. Larger buildings would have lower unit costs and wall-to-floor ratios. Planning efficiency addresses the circulation space relative to the usable space (Seeley, 1996; Kirkham, 2007, 2014; Ashworth & Parera, 2015).

5.5.2 Building shape and fullness on plan

An irregularly shaped building increases the envelope area and the length of external services and decreases the usable area of the building. Square buildings are assumed to be the most efficient, yet larger ones could be deep and require more lighting, ventilation and air-conditioning. The fuller the plan is, the more rooms and the more internal divisions would be required. A deep square building would require more internal divisions that could require more circulation areas, possibly affecting the building's efficiency and compromising the building's shape (Seeley, 1996; Kirkham, 2007, 2014; Ashworth & Parera, 2015).

5.5.3 Height and storey height

Tall buildings are more expensive to build than low-rise buildings due to, amongst other aspects, the increased foundation specification, additional area for vertical services, lifts, additional lighting and ventilation. Increased storey heights could be required to accommodate services (Seeley, 1996; Kirkham, 2007, 2014; Ashworth & Parera, 2015).

5.5.4 Other factors

Several more factors, including buildability, construction details, structural forms, pre-fabricated materials, and the like, are related to commercial buildings and are therefore not applicable to the simple residential buildings on which this research is based.

5.6 CURRENT REPLACEMENT COST ESTIMATION SOFTWARE AND METHODS

Several cost models exist specifically for calculating replacement cost estimates for insurance purposes. The most prominent existing models are:

5.6.1 The USA and Canada

5.6.1.1 Verisk Analytics Incorporated

Verisk Analytics Incorporated states that “reliable replacement cost estimates are essential to protect customers. These customers are beginning to demand a new way of doing business that puts the estimation process in their hands” and claims that their 360Value® product “helps property insurers meet evolving customer expectations while maintaining rating integrity”, that their “replacement cost estimates are grounded in actual claims experience” as the “360Value® reconstruction cost data is compiled through extensive research, direct data feed, claims analysis and communication with 92,000 claims and building contractors”. Furthermore, they claim that “360Value® produces true component-based replacement cost estimates that account for all material and labour components needed to rebuild the particular structure.”

The process followed to create the replacement cost estimate for a specific property unfolds as follows:

Step 1: The street address, the year it was built, and the number of storeys, foundation type, number of bathrooms, number of bedrooms, floor coverings, wall finishes and the like are entered. After that, project-specific data is either filled in or automatically generated (described as prefilled) with as many as 68 property-specific characteristics.

Step 2: A list of materials, labour and equipment required to rebuild the property is generated based on the information entered. An example hereof is as in Figure 5.1:

1/2″ drywall — hung taped heavy texture, ready for paint

- Drywall screws—grabber based on 25 to 50 box
- Drywall installer/finisher
- Gypsum board ½'
- Metal corner bead
- Drywall joint compound

Figure 5.1: Verisk example
Source: Verisk (2022a).

Step 3: Replacement cost estimate is produced

It is stated that the replacement cost estimate is, on average, within 0.18% accuracy of the total loss claims on the Xactware. The illustration shows that the total loss for the example equated to $121.27 / average cost per square foot compared to the $121.13 / average cost per square foot for the replacement cost estimate (Verisk, 2022a).

Verisk's 360Value® product draws data from public records, real estate data, and underwriting and claims estimates, combining these sources with its own prefilled property-specific data. The system operates on advanced self-learning algorithms that draw the most recent and appropriate information from different sources to populate the required fields and continually refine the database. As of June 2020, 124 million street addresses in the USA were listed on the SmartSource prefill tool within 360Value® (Hopkinson, 2020; Verisk, 2022b).

Verisk analysed 450 properties across the USA and Canada to identify the property characteristics that delivered the most accurate estimated replacement cost to the known replacement cost. They identified nine primary characteristics: year built, total finishes area, quality grade, number of storeys, foundation type, finished percentage of the lowest level, exterior wall finish, garage or carport, and fireplaces. Sixteen secondary characteristics were identified: the bathroom count, floor covering, cooling system, roof covering, kitchen count, kitchen counters, heating, property slope, site access, interior wall finish, foundation shape, roof shape, average wall height, exterior wall construction, foundation material and internal wall material (Hopkinson, 2016).

5.6.1.2 CoreLogic Incorporated

CoreLogic’s bespoke replacement cost product, Risk Evaluation Solutions, is also employed throughout the USA and Canada. Similar to Verisk, it is based on a component methodology that covers building construction research on labour, materials and equipment and relies on prefilled property-specific data that is sourced. The system is developed from multiple public and proprietary real estate sources (CoreLogic 1, 2024).

5.6.1.3 e2Value

e2Value, through their Pronto®, claims to offer **“**the online replacement cost valuator for residential and commercial properties that delivers instant insurance values” by “only needing to enter the property address for Pronto® to deliver a complete report that includes data scoring, images and a structure valuation”. They also claim their product is the “answer to one of today’s greatest challenges for property insurers, which is the need for simultaneous improvement of the customer experience while increasing efficiency through the use of a cost-effective process and capturing property data in a format and location that makes it readily available for ongoing analysis.”

e2Value employs EVS™ software and multiple data sources to calculate the replacement costs using a web-based standardised approach. The EVS or Expert Valuation System claims not to be modified versions of computer-based programs, thus avoiding system crashes from too many users.

5.6.2 The UK

5.6.2.1 Royal Institute of Charted Surveyors (RICS)

The BCIS (Building Cost Information Service)’s Rebuild Online, which resides under the Royal Institute of Chartered Surveyors (RICS), is used in the UK.

The BCIS was commissioned by the Association of British Insurers (ABI) to develop this product to provide general guidance in checking the sum insured of a property. The Rebuild Online system requires the following input for houses and bungalows:

- Property type with a house, bungalow, purpose-built flat or converted flat as options.
- Property details with options for style (detached, semi-detached, or terrace), number of storeys (bungalow, 2 to 4), postal code, approximate year built, external floor area (m^2 or ft^2), number of bedrooms (one to six), number of bathrooms (one to six), number of garage spaces (zero to four), type of wall (brick or stone), roof type (tile, slate, flat, thatch), cellar (yes or no), and listed or unusual property (historical properties) (yes or no).
- Property details required for purpose-built flats are the number of flats per floor (two to ten), number of storeys (two to four), postal code, approximate year built, gross internal floor area (m^2 or ft^2), number of bedrooms (one to four), number of bathrooms (one to four), number of garage spaces (zero to two), type of wall (brick or stone), roof type (tile, slate, flat), listed or unusual property (historical properties) (yes or no) and;
- Property details required for converted flats are the number of flats per floor (one or two), style (detached, semi-detached, terraced), number of storeys (two or three), postal code, approximate year built, gross

internal floor area (m^2 or ft^2), number of bedrooms (one to four), number of bathrooms (one to four), number of garage spaces (zero to two), type of wall (brick or stone), roof type (tile, slate, flat), and listed or unusual property (historical properties) (yes or no).

The input for houses and bungalows, purpose-built flats and converted flats amounts to answering 12 questions each for the property style and property details. The model includes allowances for external works, demolition costs and professional fees (RICS, 2018b, Rebuild Online, 2021).

The model returns an estimated rebuilding cost and qualifies the estimate by stating that it is reasonable based on typical facilities. It gives a bracket for whether the house has minimal facilities or is of excellent quality. The information selected is listed. The assumptions the estimate is based on are also listed, for example, an explanation of the external works allowance (RICS, 2018b; Rebuild Online, 2021).

5.6.3 Australia and New Zealand

Cordell Sum Sure of the Cordell Information (Pty) Ltd., supported by CoreLogic, is extensively used in Australia and New Zealand. This cost model is marketed as a product that helps insurers and homeowners tackle the sum insured challenge.

The Cordell Sum Sure is also based on a questionnaire containing 65 questions, with 21 questions pertaining to items of external works. The model output is a confirmation of the electives and a single sum for the replacement cost (Cordell Information Systems, 2024c).

The questions included in the questionnaires intend to address the design cost parameters referred to above, such as the number of bedrooms and bathrooms, type of walls and roof covering, and the like.

The Cordell Sum Sure draws on the integrated property data covering 99% of New Zealand's and 98% of Australia's properties. For most addresses, homeowners can enter their addresses, view the property information stored on the system, and update the gaps in the information. The replacement cost calculation is based on the granular Cordell building cost data in the system that quantity surveyors, builders and insurers verify. The calculator output is component-based and includes all the necessary material, labour, subcontracting, and plant costs (CoreLogic, 2024b; CoreLogic, 2024c).

5.6.4 South Africa

Products similar to CoreLogic, Verisk, eValue, and Rebuild Online do not exist in South Africa. Limited building cost calculators are available in the public domain. These, however, do not incorporate the level of detail that the products used in the UK, USA, Canada, Australia and New Zealand do.

5.6.4.1 Lightstone Property (Pty) Ltd

A South African company that offers residential property information, Lightstone Property (Pty) Ltd, was founded in 2005 and purports to provide services to insurers, estate agents, valuers, municipalities and other property practitioners (Lightstone, 2024a).

Their system generates a property risk report for insurance purposes that relies solely on prefilled information from the deeds offices. This information is:

- The property location, including the province, municipality, suburb, street and house number, postal code, legal description and the latitudinal and longitudinal coordinates
- The property attributes including the property type (for example, freehold or sectional title), last sales date, last sales price, registered land size, cadastral land size, estimated size under roof and the age of the property
- Owners' details
- Bond detail
- Imagery
- Property values include an estimated value with an expected low, a high, and a replacement cost value.

The property risk report disclaims that Lightstone Property (Pty) Ltd obtains data from various third-party sources, and although proprietary data cleaning processes are applied, the accuracy of the information provided is not guaranteed and is expressly not intended as professional advice (Lightstone, 2024b).

5.6.4.2 Insurance companies

The larger South African insurance companies offer building calculators for residential replacement costs on their websites. The calculators of Santam and Outsurance (2023) were tested to establish what they entailed and what results they produced.

Santam introduces their building calculator by asking how many structures there are on your property, what you think the replacement value of your property is and whether your property is on a slope. It continues with the following questions:

Category of building:	Residential, Commercial or Agricultural
What type of structure is it?	Building, Improvements, Walls and fencing
What type of building is it?	House, Granny Flat, Rondavel, Garage, Staff accommodation, Sectional title low rise office or retail

House type?	Reconstruction and Development Programme (RDP) house, Economic house, Standard house, Middle-class house, Luxury house, Exclusive house, Standard log or timber house, Luxury log or timber house
How many square metres is it?	The sliding scale is capped at 500 m^2
What is the quality of the structure?	Standard, In-between, Expensive
Other structures	Wall and fencing (15 options) Length asked Gate with single or double driveway

The calculator is qualified as follows: “The calculations provided by these calculators are based on the information provided by you and are only an estimation of the value of the asset. You should not accept the calculations to be the actual value thereof. Although Santam has made every effort to ensure the accuracy of these calculators, Santam does not guarantee, either expressed or implied, the accuracy and completeness of these calculators. Santam does not accept any liability for loss or damage of whatsoever nature which may be attributable to the reliance on and use of these calculators. Although the calculators will remain valid for 12 months, we may make changes to the Building Calculator without any notice of such changes. Calculations must, therefore, be regularly renewed to remain active” (Santam, 2022).

Outsurance (2023) describes its building calculator as “nifty”. The insurance portal requires additional questions to be answered before navigating to the building calculator. Apart from questions related to the buildings themselves, there are several questions related to risks to which the properties could be exposed. The questions pertaining to buildings are:

- Building type: House, townhouse, flat ground floor, flat above ground floor, garden cottage, storage centre, steel ship container, commercial property, park home, non-mobile caravan.
- Building construction: age of the building, number of bedrooms, wall material (brick and plaster, timber, asbestos, steel, concrete, clay, corrugated iron, gypsum alternative).
- Roof type (pitched, flat, sawtooth).
- Roof material (slate, tiles, treated thatch, thatch, IBR, iron/aluminium, asbestos, concrete, timber, malthoid, glass, canvas).
- Additional structures: swimming pool, thatched *lapa*, water heating system, none.
- Solar panels on the roof: (yes, no).
- Security measures: infrared beams (alarm only, linked to armed response), alarm system (alarm only, linked to armed response), gates (on all opening and sliding external doors, electrically operated gates), burglar bars (on all opening and non-opening windows), patrol (24 hrs), access control (24 hrs), dogs (above and below 10 kg),

electric fence (around the property, around the property linked to alarm), none.

The building cover calculator offers the following choices:

- Type of main building (sub-economical, economical, standard, middle class, luxury, exclusive, exclusive super luxury).
- Main building roof type (standard roof, slate / thatch roof).
- Type of outbuilding (outbuilding, granny flat / cottage, domestic quarters, garage, prefab concrete garage).
- Carport (shaded single, shaded double, covered single, covered double).
- Boundary wall and fencing (face brick 1,80 m high, brick and plaster 1,80 m high, precast / face brick 1,80 m high, precast slatted / timber 1,80 m high, wire mesh, electric fencing, palisade fencing, razor wire rolls 0,50 m, brick with steel fence OMB, pool fencing).

The calculator further advises that 15% should be added to the outcome of the estimate to cover professional fees, municipal fees, demolition charges, debris removal and costs to safeguard the site.

5.7 SUMMARY

The overview of procurement strategies that determine the price determination methods for constructing buildings, the traditional built environment cost models and their relationship to the design development stage, factors that influence the costs, the cost models' expected accuracy and how these are incorporated into the cost models currently used for estimating replacement costs for buildings painted a clear picture of how building costs are generated.

The details on the cost models currently used to determine replacement cost estimates demonstrate that the automated quantity surveying techniques simulate several historical cost models. The Verisk 360Value®, CoreLogic's Risk Evaluation Solutions and e2Value's Pronto® and EVS™ software all produce outputs that are hybrids between product-based and process-based estimating and rely heavily on public databases.

The models employed in the United Kingdom resemble the bill of quantities cost model the closest. All the models require the users to be informed about measuring systems and building technology. The inputs required are attempts to counter the influence of the design factors.

The models used in South Africa are the crudest and least accurate, as their intended purpose is early cost advice on building projects. The calculator inputs also attempt to counter the influence of design factors.

The accuracy of the models used in the United States, United Kingdom, Australia, New Zealand, and Canada can be regarded as in the range of low

-3% to -5 % and high +3% to +10%. However, the South African models' accuracy range must be regarded as low -10 to -20 and high +20 to +30.

CHAPTER 6: GENERATION AND PRESENTATION OF THE DATA

6.1 INTRODUCTION

Every built environment project is rich in data, including the design data, material and workmanship specification, quantification and cost data. The collecting, capturing, using, and maintaining of data needs careful thought.

Data quality depends on completeness, accuracy, consistency, timeliness and uniqueness. Completeness refers to how much data has been completed compared to how much data exists. Accuracy indicates the correctness and truth of the data. Consistency suggests that data is defined and represented similarly for all observations. The timeliness addresses the availability of data for use and to what extent the data represents the current conditions. The uniqueness points to data being entered only once into a set (Gupta & Cannon, 2020).

The preceding chapter established software currently employed in the USA, the UK, Canada, Australia and New Zealand to determine the replacement costs of residential buildings for insurance purposes. The software uses algorithms to simulate manual processes applied before the quantity surveying profession was digitised. The output these automated processes deliver resembles bills of quantities and derived versions. It is common cause that the methods and production processes of bills of quantities are the most time-consuming and require specialised knowledge of building technology and standardised measurement methods. These methods are also the most accurate cost models for buildings developed to date and, therefore, are still intensively applied in quantity surveying practice.

The South African scenario differs from the USA, the UK, Canada, Australia, and New Zealand as no evidence exists that sophisticated software for determining the replacement cost for buildings, specifically residential buildings, is available to the public. The least accurate cost model, the superficial method, is generally applied via the calculators on some insurance companies' websites.

Regardless of the intended use of the cost model, in this case for insurance purposes, cost modelling, as commonly practised in quantity surveying, would form the basis for developing an alternative cost model to encourage the uptake of a proposed alternative cost model into quantity surveying practice and for insurance purposes. The requirements for data development, the tools employed in developing the data and the data itself are discussed in the following section.

6.2 DATA

Accurate, reliable, controllable and verifiable data, datasets and databases are the cornerstones of good research. Data is measurements or observations presented in numbers or text, whereas datasets are structured collections of data associated with specific work and databases are oenerated is regarded as a dataset.

This research focuses on developing a cost model that produces more accurate replacement cost values for residential buildings than the models currently employed in South Africa. Therefore, the building cost data is designed and presented to easily apply the tools used during the proposed CBR technique. Developing the dataset for this research required developing raw data.

6.2.1 Completeness of the data

Data is considered complete when the dataset has all the necessary and relevant information for a given purpose. The dataset used in this research had to be explicitly created for the purpose of this research as no similar datasets exist in the South African public domain. Although the dataset is relatively small and comprises only 45 cases, it is sufficient to serve as the basis for this experimental research. The data for each case contains all the necessary and relevant information and can thus be regarded as complete.

6.2.2 Accuracy of the data

The preceding chapter elaborated on the accuracy of cost models used by quantity surveyors at different stages of building design development. The methodologies applied in developing the data and the reasoning behind applying these specific techniques in the context of this research are paramount.

Bills of quantities are still regarded as the most accurate form of quantification for determining a tender amount for any building. One of the primary advantages of compiling bills of quantities is creating a uniform basis for adjudicating competitive tenders. The true key to creating a uniform basis is the standardised measurement method applied in the quantification process. In the South African context, two measurement systems published by the ASAQS exist that could be used for measuring residential buildings. The first is the Standard System of Measuring Building Work for Small and Simple Buildings 1999 (SSMSSB), and the second is the Standard System of Measuring Building Work (7th Edition) 2015 (SSM7). Due to the low level of quantity surveying involvement in the residential market, the SSMSSB has not gained much traction and is seldom, if ever, used in practice. The fact that the SSMSSB has not been revised since 1999 is evidence hereof.

The SSM7 is designed for measuring all types of buildings, whether they are complex commercial buildings or simple residential buildings. The measurement principles apply equally to all designs. Hence, this system has been used to measure the residential buildings included in this study. The SSM7 comprises twenty-six measurable trades. The trades and measurement rules therein do not apply equally to every design. Sound knowledge of the measurement system and its application is thus essential.

6.2.2.1 Trades versus elements

The detailed measurements performed in accordance with the SSM7 were arranged according to trades. The rationale behind organising bills of quantities according to trades is that all similar work, such as timber elements, carpentry, and joinery trade, is grouped. It makes for more straightforward pricing instead of items similar in nature being spread over several trades or sections of the same document that could inevitably lead to a human error creeping in in the form of inconsistent pricing for the work similar in nature or the same. An example of work that is the same that could occur in several sections of the building is one brick wall that could occur in the foundation walls, the superstructure walls and the boundary walls.

The planning and construction of buildings are performed according to elements and not trades. An element of a building is defined as the significant part of the building that is common to most buildings (any type of building), that has a considerable influence on the cost of the building, and that performs a given function regardless of the design, specification, construction method or materials used (ASAQS, 2016; Kirkham, 2007). An example of an element is the substructure of a building that has the purpose of making the building stand up straight and could be in the form of strip footings, raft foundations or piling.

The elemental estimating technique occurs earlier in the design development process than creating bills of quantities. It is regarded as a compromise between the relatively easy and quick square metre method and the more cumbersome and detailed take-off required for bills of quantities. For any estimating method, fewer quantities are measured than for the more accurate and detailed cost models. The pricing becomes more involved as the quantities of several measurable items under a detailed take-off method are combined, which requires a price build-up of the combined items to be incorporated accordingly. The combined measure is often generated in a different unit of measurement than what is necessary for the detailed take-off. The unit rates of the detailed take-off must then be converted to fit the unit of measurement for estimating purposes. An example is strip footings, where one combined item would be measured for the estimate in linear metres. Still, the detailed quantities would entail measuring six separate items, for example, excavations in cubic metres, risk of collapse of excavated surfaces in square metres, backfilling to trenches in cubic metres, concrete in strip footings in cubic metres and brickwork in square metres on elevation. The unit rates for these detailed items would then need to be converted to suit the linear metres measurement of the estimate.

Insurance requires the quantification and pricing of building work to be as accurate as possible. The indemnity principle requires insurers to place the insured that suffered damage in the same position as before the damage occurred. The approach in this research was thus to apply the most accurate method to create construction costs and convert the costs to represent elements. The elemental costs could also assist a claims handling scenario. Rarely would an entire building be destroyed.

In many cases, the damage to buildings is caused by electrical faults. The damage could thus be contained in the roof area. Knowing the cost of the roof element could assist in the insurance claim.

6.2.2.2 The elements

The International Cost Management Standard (ICMS), introduced in 2017 by the ICMS Coalition, aims to provide global consistency in classifying, defining, measuring, recording, analysing, and reporting construction costs.

Every global region would still apply their standardised measurement rule, estimating rules and the like, but arrange the costs according to the ICMS framework. The South African standards are the Standard System of

Measuring Building Work, Seventh Edition (2015) for compiling bills of quantities and the ASAQS Guide to Elemental Estimating (2016) for estimating. The ASAQS Guide to Elemental Estimating elements are closely aligned with those proposed in the ICMS framework. Therefore, the structural planning of the data in this research can be regarded as aligned with international standards.

6.2.3 Consistency of the data

The data creation process needs to be adequately documented to have a common understanding of what the data represents. The data documentation is referred to as metadata (or data about data), needs to provide the context, methods and tools employed in data generation that fully describes and explains the data to make it easier to retrieve, use and manage (Tulane Universities Libraries, 2022; Smithsonian Libraries, 2018). The actual document outlining the metadata, referred to as the data dictionary, must include at least the creator of the data, when and why data was collected, what the data has measured or described, the methodologies used in creating or collecting the data and calculations applied to the raw data must be explained. Furthermore, the description of data elements must include element names such as data labels, column headings, definitions of the elements, and units of measurement (Smithsonian Libraries, 2018). The insurance of the reproduction of any research and its transparency and reusability is imperative. The FAIR principles of data being findable, accessible, interoperable and reusable should be applied for good data management. Data's findability requires rich metadata and must be available on a searchable resource. The aim of data accessibility is that it is open, free and universally available. Several well-curated, deeply integrated and special-purpose repositories exist. Still, most data types and datasets do not fit these repositories, which has led to the development of general-purpose data repositories. Thus, the FAIR principles do not dictate any specific technology, standard or specification but focus on consistency in data creation (Wilkinson, 2016).

The preceding chapter elaborated on the need for accurate data for residential property insurance purposes and the techniques traditionally used by quantity surveyors at different stages of the design development process of buildings. The methodologies applied in developing the data and the reasoning behind applying these specific techniques in the context of this research are discussed in this chapter.

6.2.4 Timeliness of the data

The availability of datasets in the South African context is problematic, as no building cost databases are publicly available. However, the custom-created dataset for this research is based on nationally standardised measurement methods and thus represents current conditions in the South African built environment.

6.2.5 Uniqueness of the data

Care was taken to ensure the uniqueness of the data. Each of the forty-five cases was separately developed and entered into the dataset.

6.3 CASE-BASED REASONING

The South African built environment incorporates the latest technologies such as digital twins, blockchain, 3D printing, laser scanning, drones and the like, introduced by the Fourth Industrial Revolution into day-to-day activities in practice. The uptake of these technologies is limited. However, the fundamental responsibilities of meeting the critical project metrics of time, cost and quality remain the priority. Substantial progress has been made in adopting the digitisation of processes through the computers, electronics, and telecommunications introduced by the Third Industrial Revolution. The uptake of digitisation in the South African built environment was only adopted in the late 80s to early 90s. The software adopted in quantity surveying practice is extensively based on algorithms that simulate the manual processes performed before digitisation. Machine learning techniques have been explored by international academia but have not gained traction in practice.

The methodology that this research's empirical part is based on is case-based reasoning (CBR) or case-based learning (CBL). Aamodt and Plaza (1994) describe CBR as a problem-solving paradigm that utilises specific knowledge of previous experiences to solve new cases. Cases are the individual projects entered into the dataset or database applied in performing the procedure. Reasoning implies human action, whereas learning refers to machine intervention or machine learning techniques that execute the CBR or CBL methodology (Kolodner, 1992). The choice of tools to implement the method thus determines the terminology to be used. CBR, or CBL, is the process of using and adapting solutions to existing cases to solve new cases. The method comprises four distinct stages. Kolodner (2014) designed the first automated case-based reasoner (Aamodt & Plaza, 1994) and described the stages as recalling a case, adapting or analysing and fixing the recalled case, evaluating the adaption and integrating the new case into memory. Aamodt and Plaza (1994) proposed the terminology of retrieving, re-using, revising and retaining cases. This terminology has been widely adopted by CBR and CBL researchers.

CBL was adopted from the cognitive psychology research by Robert Schank, who developed a theory of learning and remembering based on retaining experience in a dynamic and evolving memory structure. Using past cases when learning to solve new problems is the preferred method of experts as it is based on learning from experience. Well-worked-out methods to extract relevant knowledge from any experience, apply it to new cases, and index the cases so that they can be integrated into the existing knowledge base for subsequent matching with other similar cases leads to effective learning through CBR of CBL (Aamodt & Plaza, 1994).

The CBR cycle depicted in Figure 6.1 shows the high-level stages of retrieving, re-using, revising and retaining but also indicates tasks to be performed in these stages. The tasks vary considerably depending on the problem type that drives the process and how the tasks are performed. No universal method for performing the tasks exists. Therefore, methods suited for problem-solving and learning in a specific domain for each stage need to be designed. The first and most important task is the knowledge presentation for the model (Aamodt & Plaza, 1994).

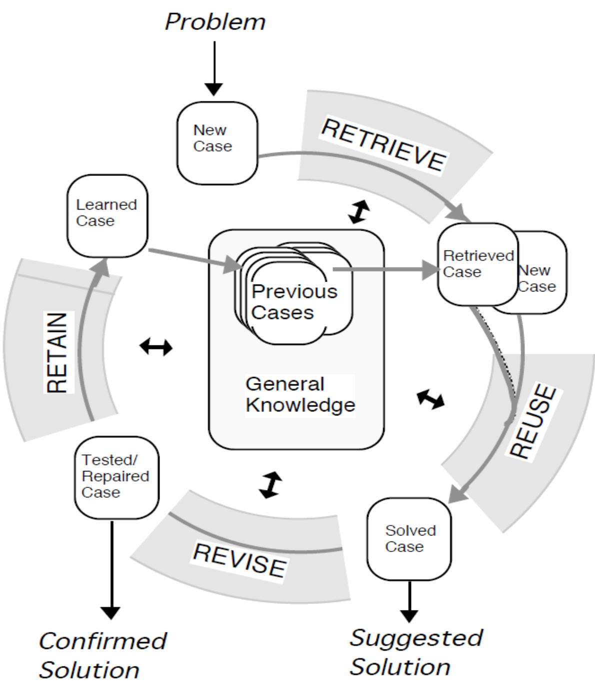

Figure 6.1: The CBR Cycle
Source: Aamodt and Plaza (1994)

Watson (1999) emphasises and supports Aamodt and Plaza's (1994) view that CBR is a methodology and not a technology, as it is often described in artificial intelligence terms because many technologies can be used in the different stages of CBR.

6.3.1 Knowledge representation

Data is sometimes viewed from a statistical perspective and sometimes from a computer science perspective. The differing terminology for the same thing is confusing. The statistical perspective would, for instance, describe the output as a specific function (f) of the input. The data in the columns will then be referred to as input variables (the known data) or the output variables (the unknown data to be sought). Typically, there would be more input variables that would then be described as the input vector. The input is also called an independent variable, and the output is a dependent variable. In machine learning equations, Y is used for the output and X for the input (Brownlee, 2019). These are depicted as:

$Output\ variable\ = f(Input\ variable)$ or

$Dependent\ variable\ = f(Independent\ variable)$ or

$Y\ = f(X)$ and for multiple inputs $Y\ = f(X1, X2, X3)$

The computer science perspective refers to the input as an entity, observation or instance and the data in the columns are referred to as attributes or features of the observations. Machine learning focuses on prediction and is thus referred to as predictive modelling. These are depicted as

$$Output\ =\ Program(Input\ Features)\ \text{or}$$

$$Prediction\ =\ Program(Instance)$$

The terminology of output variables and features is adopted for this research. The purpose of employing predictive modelling is to predict the output as accurately as possible; hence, there is little interest in the function (f) that describes the shape or form of the data, such as a linear regression line. Because the function is not addressed in the prediction model, there is an estimation error, and the expression instead is (Brownlee, 2019)

$$Y\ =\ f(X) + e$$

The chosen algorithm (k-Nearest Neighbour) for retrieving cases in this research is discussed in the next section. The importance of the error log generated when determining the number of neighbours is discussed and illustrated in the next chapter. This algorithm uses the entire dataset for prediction; hence, the data's consistency is paramount (Brownlee, 2019). This view is confirmed by Aamodt and Plaza (1994), who allude to the importance of the structure and content of the data.

6.3.2 Retrieving cases

The retrieving function is the most crucial step in CBR, as the revising result heavily relies on the similarity's accuracy. Retrieved cases (or instances) serve two purposes. Firstly, they provide context to understand and assess the new case because they provide concrete evidence for or against a solution, and secondly, they suggest solutions for the new case. The purpose of retrieval is to retrieve cases with features that can potentially make relevant predictions about new cases (Kolonder, 2014).

The use of algorithms facilitates predictions without creating specific programming. The kNN algorithm selected to retrieve the cases in this research is classified as supervised and non-parametric, meaning that all the data in the dataset is labelled and that the form of the mapping function is not assumed. Predictions are, therefore, made solely based on the most similar patterns to the case to be solved (Brownlee, 2019). Supervised learning problems are either classification problems or regression problems, where the output of a classification problem would be a category; for example, a test was passed or failed.

In contrast, the output of a regression problem is a real number, for example, monetary value, length, square metres and the like. In the process of supervised learning, an algorithm will offset bias against variance. Bias refers to assumptions made about the form of the data. Making no assumptions about the form renders the kNN low-bias. Variance refers to the degree of change in a prediction when a training data set is changed. Ideally, the change should not be too significant, indicating the algorithm's ability to detect the underlying mapping of the input and output variables. High variance thus suggests the algorithm's sensitivity to the features in the training data set. The bias-variance trade-off for the kNN happens in the adjustment of k (Brownlee, 2019).

kNN is also called a lazy learner, which refers to the fact that no actual learning takes place with this algorithm, as it simply uses the entire dataset to search for the nearest neighbours. kNN employs a distance measure to determine the nearest neighbours. Several distance measures are used in statistics and machine learning. Still, the most popular measure for determining real-valued inputs, such as presented in this research, is called the Euclidean distance. Euclidean distance is calculated as the square root of the sum of the squared differences. The difference between points (a) and (b) would thus be expressed as:

$$\sqrt{\sum_{i=1}^{n}(a^{i} - b^{i})^{2}}$$

The prediction is based on the mean or the median of the k-most similar cases for a kNN regression problem.

Kolonder (2014) refers to selecting the nearest neighbours as a ballpark solution. She emphasises that cases must be addressed as a whole and not be deconstructed and reconstructed from individual components. This is true for built environment problems, too. Deconstructing a case into the individual elements and then reconstructing the solution from the individually selected nearest neighbours for each element would skew the solution, seeing that each case comprises elements with specific relationships.

This is particularly true for built environment costing. There would be vastly varying unit rates for the same measured items in different tenders. Similarity searches based on individual measurable items and unit rates should thus be conducted with caution.

6.3.3 Re-using cases

Re-using a case examines how the new case differs from the historical cases retrieved and what part of the case can be re-used. The re-use can be based on the previous solution, or the method used to solve the previous case (Aamodt & Plaza, 1994).

Re-use in this research is based on comparing the chosen cases' features with the retrieved cases' (nearest neighbours) features.

6.3.4 Revising cases

Revising a case involves one of two processes. The first is to evaluate the case solution, and the second is to repair the case by implementing domain-specific knowledge or input (Aamodt & Plaza, 1994).

The domain-specific knowledge in this research is expressed through the features explicitly developed to revise the retrieved cases, as they represent aspects that severely impact building costs. A mathematical model is designed for this purpose.

6.3.5 Retaining cases

Retaining a case involves selecting cases that are useful for future selection. For this research, an acceptable accuracy level is set for the predicted estimates as criteria for retaining a case. Retained cases must be indexed in the same form as existing cases to serve the purpose.

6.4 DIGITISATION IN THE BUILT ENVIRONMENT

A recent global study conducted by the RICS (2023) found the measurement rules for estimating, cost planning, and procurement to be the second most important driver behind adopting data and technology after education, training and professional registration.

Employing the South African measurement rule standards constantly used in practice to generate the data for this study can, therefore, not be underestimated.

6.5 CASE-BASED REASONING IN THE BUILT ENVIRONMENT

An overview of CBR research in the construction management domain, based on the analysis of peer-reviewed journals published between 1996 and 2015, was undertaken by Hu *et al*. (2016) to understand the status of CBR research in the built environment. Despite CBR's suitability for solving construction management problems, its application is unclear due to various techniques for determining case similarity, different trends in model development, and application fields. The journal article content analysis identified 91 papers in 33 journals, revealing that most journals were from the engineering domain, emanating from South Korea, only 37,4% of articles discussed the case information method development, and only 20,9% of papers addressed the retrieval of cases.

The most popular fields to which CBR was applied are construction cost estimation (28 papers), construction tendering, bidding and procurement (12 papers), environment and sustainability management (11 papers), and construction planning and scheduling (9 papers) (Hu *et al*., 2016). Various technologies, such as artificial neural networks, genetic algorithms, and the weighted Euclidean distance, were employed for selecting similar cases, whereas attributing the feature importance of weights was performed by techniques such as feature counting, gradient decent method, genetic algorithms, equal weights, analytical hierarchy processes, multiple linear regression, ordinary least squares and modal linear regression (Hu *et al.*, 2016; Dogan *et al*., 2006; An *et al*., 2007; Ji *et al.*, 2011; Xiao, 2023).

The reliability of the CBR method is heavily reliant on the data structure, the similarity selection and the feature weighting. The CBR research referred to before mainly proposes early-stage estimating. The chosen features are thus commensurate with the low level of design development. This research proposes incorporating high-level design development features which simulate the complete residential buildings represented by the cases in the dataset.

The RICS (2023) study revealed that just 9% of the participants used artificial intelligence and advanced computational tools on most or all of their projects. This outcome could be skewed towards the Asia Pacific region, which constitutes 37% of the participation. The proposal contained in this research is novel in the South African context.

6.6 DATA PRESENTATION

The data developed for this research consists of three sections: the estimated replacement costs arranged in elemental costs, the unit rates used for pricing the quantities to arrive at the replacement cost, the features that describe the cases, and those that will be used to estimate new cases.

6.6.1 Estimated elemental replacement costs

The data is reflected in the order of capturing. As explained in the accuracy of data, each house or case was measured according to the standardised measurement method for trades and then converted to the elements as displayed in Table 6.1. The structured nature of the data is evident from the layout.

Table 6.1: Estimated elemental replacement costs

House	m²	Replacement cost	Ground floor construction	External elevation	Roof (on the slope)	Internal divisions	Furniture, fixtures & equipment	Services (plumbing)	Services (electrical & mechanical)
1	51	328 000	50 043	98 009	66 579	43 849	3 361	39 402	26 757
2	60	356 600	58 470	106 771	76 733	43 799	3 920	40 384	26 523
3	65	386 600	60 664	112 513	83 396	43 739	6 160	53 330	26 798
4	70	407 300	64 351	127 167	85 015	44 055	6 160	53 729	26 823
5	72	449 500	65 481	132 821	101 201	47 105	6 664	68 485	27 743
6	84	493 900	74 139	140 706	122 678	53 298	6 664	68 619	27 796
7	240	1 461 300	251 966	429 584	236 353	138 117	207 764	96 994	100 522
8	186	1 109 000	247 007	314 513	176 677	85 151	90 307	84 791	110 536
9	145	978 300	219 205	260 414	185 069	106 335	83 157	57 297	66 823
10	285	1 526 000	333 595	371 816	303 001	196 400	83 864	82 603	154 721

11	346	2 098 000	401 728	316 500	525 962	261 410	178 365	154 565	259 470
12	379	2 312 500	501 255	372 239	386 940	410 739	252 901	175 675	212 751
13	373	2 102 300	472 147	294 710	398 069	236 222	199 105	173 434	328 613
14	204	1 259 000	262 775	186 860	205 967	211 271	113 140	126 446	152 541
15	610	2 796 500	567 747	396 834	694 555	267 506	178 750	241 980	449 128
16	360	2 268 500	570 482	234 652	404 192	319 573	273 682	158 480	307 439
17	117	880 200	180 467	168 842	166 949	69 627	86 317	125 831	82 167
18	152	877 000	155 125	176 613	208 578	131 161	106 781	42 561	56 181
19	340	2 127 60	374 357	428 890	510 926	283 097	248 569	183 368	98 393
20	283	1 722 000	285 550	299 634	431 295	195 093	268 822	104 854	136 752
21	208	1 603 000	272 816	360 505	263 067	132 294	291 353	127 877	155 088
22	341	2 138 000	428 075	329 713	346 730	223 817	192 063	361 940	255 662
23	40	324 600	45 428	94 312	55 094	27 227	47 713	35 001	19 825
24	50	371 700	53 952	108 375	67 415	34 042	47 714	36 681	23 521

25	57	435 400	70 655	117 090	80 068	45 977	57 120	38 752	25 738
26	60	452 800	66 976	103 721	88 105	44 664	65 512	56 609	27 213
27	65	514 000	74 216	122 786	101 621	50 368	73 910	56 608	34 491
28	70	535 700	73 332	127 309	99 535	50 846	90 715	55 773	38 190
29	80	545 300	75 636	131 438	127 603	47 843	65 515	55 380	41 885
30	90	651 900	87 336	144 794	136 282	47 784	133 056	57 064	45 584
31	95	612 200	92 151	148 062	126 318	60 703	82 319	55 383	47 264
32	100	751 700	98 057	156 268	137 435	69 804	185 472	55 384	49 280
33	132	972 000	151 787	277 499	176 009	85 370	110 191	111 009	60 135
34	268	1 600 000	359 572	294 377	318 642	198 783	184 465	101 864	142 297
35	102	674 900	139 605	143 771	143 816	29 719	109 030	70 230	38 729
36	76	548 900	107 502	116 087	100 932	44 134	85 381	65 116	29 748
37	444	2 323 700	360 366	416 142	685 104	200 044	305 335	189 504	167 205
38	65	464 800	69 485	110 276	101 502	49 318	45 020	61 202	27 997

39	205	1 814 000	299 843	272 283	299 497	265 898	350 042	156 666	169 771
40	405	2 081 700	313 091	500 946	468 450	200 993	240 877	189 172	168 171
41	282	1 587 300	280 166	349 638	332 088	147 348	136 916	214 251	126 893
42	119	737 700	125 501	167 746	153 958	65 573	113 234	55 385	56 303
43	51	338 200	48 866	94 230	82 021	30 373	18 818	64 296	24 396
44	55	348 400	49 478	76 706	88 059	34 353	35 620	39 541	24 643
45	60	462 500	68 954	115 155	96 538	49 118	45 029	61 215	26 491

Table 6.2: Estimated elemental replacement costs as a percentage contribution

House	m²	Replacement cost	Ground floor construction	External elevation	Roof (on the slope)	Internal divisions	Furniture, fixtures & equipment	Services (plumbing)	Services (electrical & mechanical)
1	51	328 000	0,153	0,299	0,203	0,134	0,010	0,120	0,082
2	60	356 600	0,164	0,299	0,215	0,123	0,011	0,113	0,074
3	65	386 600	0,157	0,291	0,216	0,113	0,016	0,138	0,069
4	70	407 300	0,158	0,312	0,209	0,108	0,015	0,132	0,066
5	72	449 500	0,146	0,295	0,225	0,105	0,015	0,152	0,062
6	84	493 900	0,150	0,285	0,248	0,108	0,013	0,139	0,056
7	240	1 461 300	0,172	0,294	0,162	0,095	0,142	0,066	0,069
8	186	1 109 000	0,223	0,284	0,159	0,077	0,081	0,076	0,100
9	145	978 300	0,224	0,266	0,189	0,109	0,085	0,059	0,068
10	285	1 526 000	0,219	0,244	0,199	0,129	0,055	0,054	0,101

11	346	2 098 000	0,191	0,151	0,251	0,125	0,085	0,074	0,124
12	379	2 312 500	0,217	0,161	0,167	0,178	0,109	0,076	0.092
13	373	2 102 300	0,225	0,140	0,189	0,112	0,095	0,082	0,156
14	204	1 259 000	0,209	0,148	0,164	0,168	0,090	0,100	0,121
15	610	2 796 500	0,203	0,142	0,248	0,096	0,064	0,087	0,161
16	360	2 268 500	0,251	0,103	0,178	0,141	0,121	0,070	0,136
17	117	880 200	0,205	0,192	0,190	0,079	0,098	0,143	0,093
18	152	877 000	0,177	0,201	0,238	0,150	0,122	0,049	0,064
19	340	2 127 60	0,176	0,202	0,240	0,133	0,117	0,086	0,046
20	283	1 722 000	0,166	0,174	0,250	0,113	0,156	0,061	0,079
21	208	1 603 000	0,170	0,225	0,164	0,083	0,182	0,080	0,097
22	341	2 138 000	0,200	0,154	0,162	0,105	0,090	0,169	0,120
23	40	324 600	0,140	0,291	0,170	0,084	0,147	0,108	0,061
24	50	371 700	0,145	0,292	0,181	0,092	0,128	0,099	0,063

25	57	435 400	0,162	0,269	0,184	0,106	0,131	0,089	0,059
26	60	452 800	0,148	0,229	0,195	0,099	0,145	0,125	0,060
27	65	514 000	0,144	0,239	0,198	0,098	0,144	0,110	0,067
28	70	535 700	0,137	0,238	0,186	0,095	0,169	0,104	0,071
29	80	545 300	0,139	0,241	0,234	0,088	0,120	0,102	0,077
30	90	651 900	0,134	0,222	0,209	0,073	0,204	0,088	0,070
31	95	612 200	0,151	0,242	0,206	0,099	0,134	0,090	0,077
32	100	751 700	0,130	0.208	0,183	0,093	0,247	0,074	0,066
33	132	972 000	0,156	0,285	0,181	0,088	0,113	0,114	0,062
34	268	1 600 000	0,225	0,184	0,199	0,124	0,115	0,064	0,089
35	102	674 900	0,207	0,213	0,213	0,044	0,162	0,104	0,057
36	76	548 900	0,196	0,211	0,184	0,080	0,156	0,119	0,054
37	444	2 323 700	0,155	0,179	0,295	0,086	0,131	0,082	0,072
38	65	464 800	0149	0,237	0,218	0,106	0,097	0,132	0,060

39	205	1 814 000	0,165	0,150	0,165	0,147	0,193	0,086	0,094
40	405	2 081 700	0,150	0,241	0,225	0,097	0,116	0,091	0,081
41	282	1 587 300	0,177	0,220	0,209	0,093	0,086	0,135	0,080
42	119	737 700	0,170	0,227	0,209	0,089	0,153	0,075	0,076
43	51	338 200	0,135	0,260	0,226	0,084	0,052	0,177	0,067
44	55	348 400	0,142	0,220	0,253	0,099	0,102	0,113	0,071
45	60	462 500	0,149	0,249	0,209	0,106	0,097	0,132	0,057

Analysis such as the mean and standard deviation are deliberately not performed for this data as it would not add value to the use of the data in this research's analysis based on the nearest neighbours. This detail illustrates that the bulk of the costs for each case is contained in the ground floor construction, the external envelope and the roof elements, with the smaller cases' external envelopes dominant and the larger cases' roofs dominant.

6.6.2 Unit rates

The unit rates used to price the cases in this research were market-related rates for the Gauteng province, South Africa, in 2021.

Unit rates are usually adjustable for time and location and would vary for different tenders. This research, however, intends to test the proposed cost model without factoring in adjustments for these anomalies. Therefore, standardised rates were used to cost the measured houses. The rates used are set out in Table 6.3.

Table 6.3: Unit rates

	DESCRIPTION	UNIT	RATE
1.0	**Earthworks**		
1.1	Site clearance	m^2	25.00
1.2	Excavate for trenches	m^3	180.00
1.3	Extra over excavations in trenches for soft rock	m^3	450.00
1.4	Extra over excavations in trenches for hard rock	m^3	850.00
1.5	Risk of collapse to sides of excavations	m^2	15.00
1.6	Filling under floors from excavations	m^3	185.00
1.7	Backfilling in trenches from excavations	m^3	185.00
1.8	Coarse river sand under floors	m^3	525.00
1.9	Soil poisoning under floors and in trenches	m^2	25.00
2.0	**Concrete, Formwork and Reinforcement**		
2.1	25 MPa/19 mm concrete in strip footings	m^3	1 350.00
2.2	25 MPa/19 mm concrete in surface beds	m^3	1 350.00
2.3	Mesh ref 193 reinforcement	m^2	45.00
2.4	Formwork to edges	m	105.00
3.0	**Masonry**		
3.1	Mass brickwork	m^3	1 900.00
3.2	Half brick walls	m^2	210.00
3.3	Half brick walls in beam filling	m^2	220.00
3.4	One brick walls	m^2	420.00
3.5	220 mm Brick-on-edge copings	m	95.00
3.6	75 mm Wide brickforce	m	3.00
3.7	150 mm Wide brickforce	m	5.00
3.8	70 x 100 mm High Precast concrete lintel	m	75.00
3.9	4 mm Diameter roof ties	no	15.00
3.10	Face brickwork	m^2	185.00
3.11	150 mm “Nutec” fibre cement sill	m	85.00
3.12	Precast concrete external sill	m	85.00
3.13	60 mm Precast concrete paving	m^2	240.00

4.0	**Waterproofing**		
4.1	DPC in walls	m^2	25.00
4.2	Damp proofing under floors	m^2	25.00
5.0	**Roof coverings**		
5.1	Double Roman concrete roof tiles	m^2	185.00
5.2	Extra over for tilting batten	m	15.00
5.3	Concrete tile ridge	m	95.00
5.4	Close-cut and fitted valley	m	95.00
5.5	Hip of tile to match roofing	m	95.00
5.6	Purpose-made tile at intersection	no	125.00
5.7	0.53 mm IBR galvanised roof sheeting	m^2	170.00
5.8	150 mm Valley lining	m	125.00
5.9	10 x 225 mm Nutec fascia board	m	75.00
6.0	**Carpentry and Joinery**		
6.1	Prefabricated timber roof trusses	m^2	350.00
6.2	38 x 76 mm Wall plate	m	45.00
6.3	Two coats of creosote on timber	m^2	55.00
6.4	40 mm Solid timber two-panel door 813 x 2032 mm high	no	2 400.00
6.5	40 mm Hollow core door with Masonite finish 813 x 2032 mm high	no	850.00
6.6	Timber frame for 813 x 2032 mm high door	no	1 800.00
6.7	Ditto, for door 1 600 x 2 032 mm high	no	2 800.00
6.8	19 x 75 mm Meranti skirting	m	60.00
6.9	100 mm High-profiled skirting	m	95.00
6.10	Timber window	m^2	1 500.00
7.0	**Floor Coverings**		
7.1	Wall-to-wall carpeting	m^2	250.00
7.2	Luxury wall-to-wall carpeting	m^2	350.00
7.3	Vinyl floor tiling	m^2	350.00
7.4	Laminated wooden flooring	m^2	350.00
8.0	**Ceilings**		
8.1	6,4 mm Gypsum ceiling on 38 x 38 mm purlins	m^2	185.00

8.2	6 mm Fibre cement ceiling	m^2	265.00
8.3	Knotty pine ceiling	m^2	350.00
8.4	600 x 600 mm Trap door	no	850.00
8.5	75 mm Coved cornice	m	45.00
8.6	50 mm Insulation	m^2	45.00
8.7	120 mm Profiled cornice	m	95.00
9.0	**Ironmongery**		
9.1	Two lever lockset	no	195.00
9.2	Three lever lockset	no	220.00
9.3	Four lever lockset	no	245.00
9.4	Kirsch single curtain track	m	65.00
9.5	Kirsch double curtain track	m	95.00
9.6	End bracket plugged	no	45.00
9.7	30 mm Diameter rubber door stop	no	55.00
9.8	20 mm Diameter x 900 mm long tower rail	no	450.00
9.9	Chromium-plated toilet roll holder	no	250.00
9.10	350 x 350 mm Bathroom cabinet	no	850.00
10.0	**Metalwork**		
10.1	1,2 mm Pressed metal double rebated door frame for 813 x 2032 mm door suitable for half brick wall	no	850.00
10.2	1,2 mm Pressed metal double rebated door frame for 813 x 2032 mm door suitable for one brick wall	no	950.00
10.3	Steel residential window, 533 x 654 mm high	no	350.00
10.4	Steel residential window, 1 022 x 949 mm high	no	660.00
10.5	Steel residential window, 1 022 x 1 540 mm high	no	1 070.00
10.6	Steel residential window, 1 511 x 654 mm high	no	675.00
10.7	Steel residential window, 1 511 x 949 mm high	no	975.00
10.8	Steel residential window, 1 511 x 1 245 mm high	no	1 120.00
10.9	Steel residential window, 2 000 x 949 mm high	no	1 300.00
10.10	Steel residential window, 2 000 x 1 540 mm high	no	2 100.00
10.11	Steel residential window, 2 400 x 1 800 mm high	no	2 950.00
10.12	Steel door 813 x 20 032 mm high	no	1 500.00
10.13	Safety screens	m^2	1 500.00

10.12	Aluminium standard sliding door 1 800 x 2 100 mm high	no	8 000.00
10.13	Aluminium standard sliding door 2 400 x 2 100 mm high	no	10 000.00
10.14	Aluminium standard sliding door 2 900 x 2 100 mm high	no	12 000.00
10.15	Double steel garage door 5 000 x 2 100 mm high	no	6 500.00
10.16	Aluminium windows	m^2	2 200.00
10.17	Aluminium doors	m^2	2 500.00
10.18	Aluminium sliding stacking doors	m^2	2 800.00
11.0	**Plastering**		
11.1	25 mm Thick cement screed on floors and landings	m^2	85.00
11.2	Average 50 mm thick screed	m^2	105.00
11.3	One coat of internal plaster on walls	m^2	65.00
11.4	Ditto, on narrow widths	m^2	70.00
11.5	One coat of external plaster on walls	m^2	65.00
11.6	Ditto, on narrow widths	m^2	70.00
11.7	Ditto, on sloping top and front edge of sills	m	70.00
11.8	Granolithic on floors	m^2	125.00
12.0	**Tiling**		
12.1	White glazed tiles on walls	m^2	210.00
12.2	Ceramic tiles on floors	m^2	250.00
12.3	80 mm High-cut skirting	m	95.00
12.4	Mosaic tiles on floors	m^2	1 500.00
13.0	**Plumbing and Drainage**		
13.1	75 x 100 mm Galvanised eaves gutter	m	85.00
13.2	75 mm Diameter galvanised downpipe	m	70.00
13.3	Stopped end on gutter	no	20.00
13.4	Outlet on gutter	no	20.00
13.5	Shoe on downpipe	no	20.00
13.6	Eaves offset on the downpipe	no	85.00
13.7	300 x 500 mm Long precast channel	no	650.00
13.8	110 mm Diameter uPVC pipe vertically	m	110.00
13.9	110 mm Diameter uPVC pipe in excavations 0 -1	m	240.00

	m deep		
13.10	110 mm uPVC bend	no	75.00
13.11	110 mm uPVC access junction	no	195.00
13.12	100 mm ABC cleaning eye	no	750.00
13.13	110 mm Gulley	no	450.00
13.14	600 x 600 x 1 000 mm Deep inspection chamber	no	950.00
13.15	600 x 600 mm Cast iron manhole cover	no	1 200.00
13.16	1 000 mm Long “Citiline” double bowl sink and drainer	no	1 100.00
13.17	Floor unit for sink	no	1500.00
13.18	Vaal “Daisy” lavatory basin	no	750.00
13.19	Vaal “Aquasave” water closet	no	1 100.00
13.20	“Plexicor Carmen” bath	no	3 000.00
13.21	32 mm Chromium-plated basin waste	no	140.00
13.22	38 mm Chromium-plated bath or sink waste	no	160.00
13.23	32 mm “P” or “S” Marley trap	no	45.00
13.24	38 mm Ditto	no	55.00
13.25	38 mm Bath trap with overflow	no	125.00
13.26	40 mm Shower trap with chromium-plated grating	no	680.00
13.27	25 mm Full way gate valve	no	360.00
13.28	15 mm Brass garden tap	no	250.00
13.29	15 mm Full way ball cock	no	175.00
13.30	15 mm Cobra Star bib tap	no	565.00
13.31	15 mm Cobra Star undertile stopcock	no	750.00
13.32	15 mm Cobra Star basin mixer	no	2 250.00
13.33	50 mm uPVC pipe	m	75.00
13.34	110 mm uPVC pipe	m	160.00
13.35	110 mm Straight pan connector	no	60.00
13.36	50 mm Bend	no	12.00
13.37	110 mm Bend	no	95.00
13.38	50 mm Junction	no	25.00
13.39	50 mm Access bend	no	35.00
13.40	50 mm Access junction	no	35.00

13.41	110 mm Access junction	no	100.00
13.42	110 mm Two-way vent valve	no	100.00
13.43	25 mm Diameter class 6 HPDE pipe	m	60.00
13.44	25 mm Fittings	no	35.00
13.45	16 mm Diameter class 0 copper pipes to walls	m	70.00
13.46	22 mm Diameter class 0 copper pipes to walls	m	85.00
13.47	16 mm Fittings	no	45.00
13.48	22 mm Fittings	no	60.00
13.49	150 Litre geyser	no	5 500.00
13.50	Drip tray	no	300.00
14.0	**Electrical Installation**		
14.1	Distribution board	no	5 000.00
14.2	Earth leakage	no	950.00
14.3	Geyser isolator	no	850.00
14.4	Stove isolator	no	650.00
14.5	1,5 mm 2 x 3 Surfix cable	m	12.00
14.6	2,5 mm 2 x 3 Suffix	m	28.00
14.7	1,5 mm 2 Bare copper cable	m	12.00
14.8	Round outlet for 20 mm conduit	no	10.00
14.9	50 x 100 x 50 mm Outlet box	no	20.00
14.10	100 x 100 x 50 mm Outlet box	no	25.00
14.11	16A One lever one-way switch unit	no	150.00
14.12	16A Two lever one-way switch unit	no	180.00
14.13	16A Three-pin double wall socket	no	450.00
14.14	TV socket	no	650.00
14.15	Ball type ceiling mounted light	no	150.00
14.16	Bulkhead-type wall-mounted external light	no	250.00
14.17	Double tube fluorescent light fitting 1 200 mm long	no	850.00
14.18	Defy 3-plate compact stove	no	3 500.00
15.0	**Glazing**		
15.1	4 mm Clear float glass	m^2	350.00
15.2	4 mm Obscure glass	m^2	440.00

15.3	6,5 mm Clear safety glass	m^2	650.00
16.0	**Paintwork**		
16.1	One base coat and two coats of PVA paint on the internal walls	m^2	60.00
16.2	One base coat and two coats of PVA paint on the external walls	m^2	60.00
16.3	One base coat and two coats of PVA paint on the ceilings	m^2	60.00
16.4	One universal undercoat and two coats of enamel paint on door frames	m^2	65.00
16.5	Ditto on windows with burglar bars	m^2	65.00
16.6	Paint on gutters	m	25.00
16.7	Paint on downpipes	m	25.00
16.8	Three coats of wood preservatives on doors	m^2	65.00

6.6.3 Features

The replacement costs for the forty-five cases are presented in seven elements: ground floor construction, external envelope, roof, internal divisions, furniture, fixtures, equipment, plumbing services, and electrical and mechanical services. The features are chosen to address factors that influence the building costs and are related to the elements so that pro rata ratios for the features can be used in revising the nearest neighbours to derive the appropriate estimates.

These features are readily measurable by laypeople without specific knowledge of building technology or building costs. The intention is that people requiring estimates for their residential properties present the measurements of only these features that would be fed into the proposed cost model and present estimated replacement costs based on the elemental costs of cases contained in the prediction model.

Table 6.4: Features

CASES	Construction area	Area of structure	Roof area (on slope)	Roof pitch	External elevation area	Wall height	Area of windows and external doors	Length of external walls	Corners	Length of internal walls	Number of rooms	Number of bedrooms	Sanitary fittings	Furniture, Fixtures
1	51	9	70	17.5	74	2.44	10	30	4	19	6	3	5	1.8
2	60	10	77	17.5	85	2.44	12	32	6	24	8	3	5	1.8
3	65	10	82	17.5	88	2.44	16	33	6	22	8	3	8	1.8
4	70	10	87	17.5	91	2.44	16	34	8	23	8	3	8	1.8
5	72	11	97	17.5	87	2.4	22	36	10	26	8	3	10	1.8
6	84	12	123	17.5	97	2.4	22	40	10	26	8	3	10	1.8
7	240	23	296	27	233	2.55	69	70	10	59	15	4	17	34
8	186	23	217	15	173	2.67	34	55	4	45	9	3	10	23
9	145	24	231	23	269	2.7	34	59	9	58	12	3	5	16
10	285	35	343	23	271	2.89	49	89	6	72	11	4	6	55
11	344	46	519	15	363	2.89	62	126	8	155	14	3	8	26
12	379	64	439	10	222	2.9	88	163	8	183	17	4	15	50
13	373	35	396	10	313	2.89	111	100	22	111	16	4	12	42
14	204	30	221	10	222	2.89	25	74	10	119	11	3	10	20
15	610	50	845	45/10	448	2.7	70	154	8	137	18	6	23	44
16	360	41	442	10	290	2.85	58	91	10	88	14	3	14	42
17	117	15	159	26	160	2.98	26	48	8	36	9	3	9	13

18	152	16	217	35	166	3.36	21	49	4	42	8	3	5	15
19	293	48	418	23	366	2.57	61	137	24	162	23	4	15	48
20	283	35	462	26/45	272	2.6	36	89	14	71	12	4	8	37
21	208	25	245	18	274	2.5	36	85	8	52	11	4	13	34
22	341	39	408	5	271	2.7	63	123	4	97	21	6	23	30
23	40	7	55	27	84	2.72	14	26	6	12	5	2	4	7
24	50	8	69	27	94	2.72	15	29	6	13	5	2	4	8
25	57	9	84	26	107	2.72	14	31	8	21	8	3	4	9
26	60	10	87	26	89	2.72	9	34	6	20	8	3	7	9
27	65	10	111	26	111	2.72	16	34	8	23	8	3	7	10
28	70	11	105	26	128	2.72	18	35	8	23	8	3	7	12
29	80	12	138	26	131	2.72	16	38	10	27	8	3	7	10
30	90	12	146	26	133	2.72	19	43	10	19	9	3	7	12
31	95	12	135	26	135	2.72	20	41	8	27	8	3	7	12
32	100	13	148	26	147	2.72	23	44	8	28	9	3	7	31
33	132	18	186	45	120	3.4	50	59	8	34	6	2	11	14
34	268	29	336	24	273	2.72	55	71	8	92	18	4	13	29
35	102	13	136	26	124	2.72	27	42	6	30	7	2	6	14
36	76	10	103	26	115	2.72	18	34	4	21	6	2	6	11
37	444	24	782	45	235	2.6	56	64	10	88	16	4	12	39
38	65	10	98	32	101	2.72	14	34	8	22	7	3	7	8
39	205	27	248	23	232	2.67	54	79	6	102	16	3	13	56

40	405	47	500	45	615	3.35	53	180	24	54	14	4	13	38
41	282	27	360	17	249	2.72	45	80	6	74	16	6	15	13
42	119	16	162	17	157	2.72	25	53	10	31	10	3	7	17
43	51	8	78	32	85	2.72	12	29	6	14	4	2	4	2
44	55	10	84	32	95	2.72	10	32	10	14	5	2	4	6
45	60	11	91	32	104	2.72	12	35	10	23	7	3	7	8

6.7 SUMMARY

The requirements for developing quality data and the methods and tools employed to create the data were discussed in this chapter. The CBR methodology, according to which the data analysis will be performed, is discussed in detail to understand how it works. The methodology requires four specific steps: retrieving, re-using, revising and retaining data. The tools that will be applied during these four steps have been discussed.

The data itself is presented in the form of the forty-five cases measured and structured according to the chosen elements; the unit rates that were applied to determine the estimated replacement costs that are to serve as the benchmarks against which the results for the proposed cost model are to be measured; and the features that will be used in the prediction of the replacement costs are shown.

The data preparation is complete and ready to be inserted into the IBM® SPSS® Statistics version 28.0.1.0 (142) software for the retrieval step.

CHAPTER 7: ANALYSIS OF THE DATA

7.1 INTRODUCTION

The Case-Based Reasoning (CBR) methodology, according to which the empirical part of this research is executed, was explained in the previous chapter. This chapter demonstrates the four steps of retrieving, re-using, revising and retaining data for each dataset case.

The data was designed and structured purposefully for use in the CBR process. Determining accurate replacement costs is the target and purpose of the proposed method. The features to address the shortcomings of the cost model currently employed in the South African insurance environment were also purposefully chosen.

7.2 RETRIEVING THE NEIGHBOURS

7.2.1 The retrieval

The retrieval of similar cases by selecting the nearest neighbours is regarded as the most crucial step of the CBR process. Each case's elemental values, replacement costs and specified features are entered into the prediction model. The prediction model utilised is the k-Nearest Neighbour classification analysis tool in the IBM® SPSS® Statistics version 28.0.1.0 (142) software package.

A case one wants to determine the estimated replacement cost for is introduced into the prediction space based on its measured features. The kNN algorithm then searches the dataset and applies the Euclidean distance measure to each value and each case feature to determine which cases in the predictor space are the nearest to the case that wants to be estimated.

The significance of selecting cases similar to the case under scrutiny cannot be overemphasised. In practice, this selection is lacking because practitioners do not have well-developed datasets of similar cases to choose from. Often, a practice will not have multiple similar projects and will use the latest comparison for the same type of building but not have a clear understanding of the level of similarity. This research focuses on residential buildings, but the principles for determining the level of similarity can be applied to all types of buildings, such as office buildings, industrial buildings, and the like.

7.2.2 The elements

The elements according to which the detail measured and costed cases were arranged are set out in Table 7.1.

Table 7.1: Elements

1	Ground floor construction
2	External Elevation
3	Roofs
4	Internal divisions
5	Furniture, fixtures and equipment
6	Plumbing services
7	Electrical and mechanical services

These elements represent horizontal and vertical cost data. They are aligned to the elements as set out in the ASAQS *Guide to Elemental Cost Estimating and Analysis for Building Works* (2016), except for the finishes where floor finishes are incorporated into ground floor construction, wall finishes are incorporated into external elevation, internal wall finishes are incorporated into internal divisions and ceilings are incorporated into roofs. The motivation for incorporating the finishes into related elements is to create a structure that represents the patterns of damages in insurance claims.

Each element is made up of trades as measured according to the SSM7. The ground floor construction element comprises the excavations, concrete foundations, foundation walls, filling under floors, floor construction and floor finishes. The external elevation element comprises superstructure walls; windows complete with lintels, sills, frames, glazing and finishes; doors complete with frames, ironmongery and finishes; external finishes to walls; and internal finishes to external walls. The roof element includes the roof covering, roof structure, rainwater disposal, eaves treatment, ceilings and finishes to all the items. The internal divisions element consists of the internal superstructure walls, doors in internal walls complete with frames, ironmongery and finishes and internal finishes to both sides of walls. The furniture, fixtures and equipment element represent all built-in cupboards, shelving, fireplaces and the like. The plumbing services element comprises the sewer, sanitary pipework, water supply, sanitary fittings, geysers, shower cubicles, and sundry sanitary fittings such as mirrors, toilet roll holders, and the like. The electrical and mechanical services element includes the electrical installation, air-conditioning, alarm systems, DSTV installations, stives and extractor fans and any other electrical or electronic installations.

The trade of preliminaries provides for the managerial expenses of a building contract. The value of the preliminaries is added pro-rata to every element. The above elements exclude the cases' external works, such as the boundary walls, swimming pools, tennis courts, paving, and the like. The reason for this exclusion is that the external works is a function of the stand the residence is on and not of the actual building. The external works, that are relatively easy to estimate, would eventually need to be added to the replacement cost estimates generated by the model proposed in the research.

The elemental values for each case in the dataset were presented as part of the data in the previous chapter.

7.2.3 Specified features

Fourteen specified features were developed to address the shortcomings associated with the less accurate estimating types. The aspects to address through these features are the size, shape, fullness on plan, and the height. The features are:

Table 7.2: Features

1	Construction area
2	Area of the structure
3	Roof area on the slope
4	Roof pitch
5	Area of the external envelope
6	Wall heights
7	Area of external doors and windows
8	Length of external walls
9	Number of corners in the external walls
10	Length of internal walls
11	Number of rooms
12	Number of bedrooms
13	Number of sanitary fittings
14	Length of the furniture, fixtures and equipment

The values for each feature and case in the dataset were presented as part of the data in the previous chapter.

The predictions can either be based on unweighted features or weighted features. Weighting the features attributes the importance and relevance of specific features during the classification process. Predictions are prepared for unweighted features and weighted features to determine the impact that the weight has on the accuracy of the predictions.

The second and third steps of the CBR process entail determining which identified nearest neighbours could be re-used and how the cases need to be revised to generate the estimated replacement cost for the case under review. A mathematical model is applied for this purpose. Four of the fourteen features are not incorporated in the mathematical model. These four features are, however, addressed by measuring the roof covering on the slope, the length of the external walls and the length of the internal walls. The four features not used in the mathematical model are listed in Table 7.3.

Table 7.3: Features excluded from the mathematical model

1	Roof pitch
2	Number of corners in the external walls
3	Number of rooms
4	Number of bedrooms

Two scenarios were created for this research. One scenario is based on the fourteen unweighted features, and the other is based on the fourteen weighted features.

The predictor importance weightings allocated to the feature are 0.08 for the length of external walls, the area of external doors and windows and the number of sanitary points. The construction area, the area of the structure, the length of the internal walls, the roof area, the length of the furniture, fixtures and equipment, the area of the external envelope, and the length of the internal walls are all weighted at 0.07. The weightings for the ten mentioned features total 72,73%. Therefore, the remaining 27,27% is allocated to the roof pitch, wall heights, corners, rooms, and bedrooms. Assuming that the 27,27% is spread equally across the four features, each would contribute 0.05 to the weightings. The conclusion derived from these weightings is that all fourteen features are important, and none of the features can be discarded.

Table 7.4: Predictor importance for fourteen features (generated by IBM® SPSS® Statistics)

Nodes	Importance	Importance	V4	V5
V10	0.0697	0.0697	Construction area	0.0697
V11	0.0701	0.0701	Structure	0.0701
V19	0.0701	0.0701	Length of internal walls	0.0701
V12	0.0711	0.0711	Roof area (on slope)	0.0711
V23	0.0714	0.0714	Length of furniture, fixtures and equipment	0.0714
V18	0.0735	0.0735	Corners in the external walls	0.0735
V14	0.0736	0.0736	External envelope area	0.0736
V22	0.0757	0.0757	Number of sanitary points	0.0757
V16	0.0757	0.0757	Area of doors and windows	0.0757
V17	0.0764	0.0764	Length of external walls	0.0764

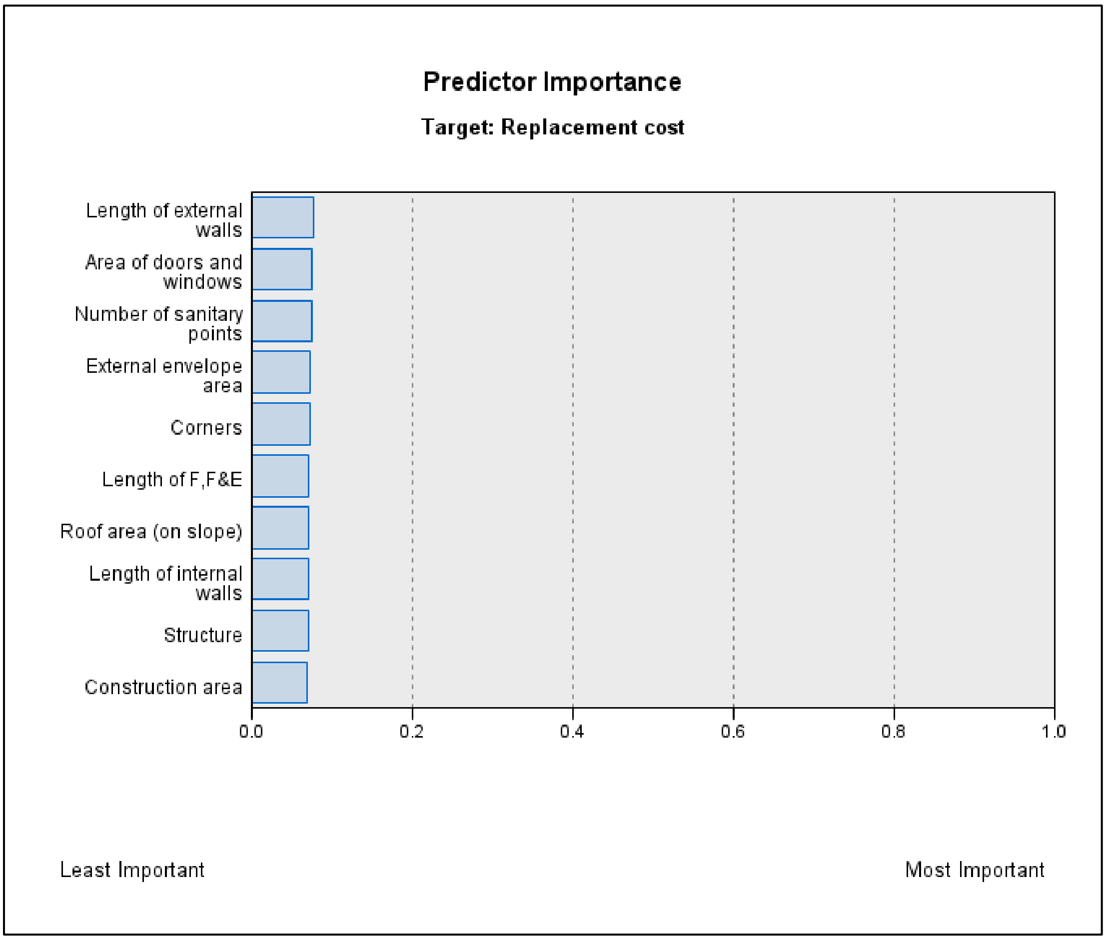

Figure 7.1: Weighting of Predictor Importance for fourteen features (generated by IBM® SPSS® Statistics)

7.2.4 Selection of k for Nearest Neighbours (kNN)

Selecting the most appropriate value for k is crucial to eliminate underfitting or overfitting, thus optimising the kNN algorithm's performance. The optimal value for k is determined by applying a cross-validation process. The cross-validation process is an alternative to dividing the data into training and testing sets, as is the case for other machine learning techniques. With the kNN algorithm, the entire data set is available for training. The cross-validation is performed by repeatedly dividing the data into smaller groups to be used in the validation process. Usually, a 5-fold or 10-fold cross-validation is sufficient. A 9-fold cross-validation was chosen to fit with the five groups in the 45 cases in the dataset. The dataset is shuffled so there is no particular order and then split into nine groups. Determining the k-value happens by selecting the test and training folds, fitting the model to the training folds, evaluating the model on the test folds and obtaining the score for k. For every iteration, one fold acts as the test data and the remaining folds as the training data. The test and training folds change for every iteration to ensure the model's effectiveness.

The k applies to both scenarios, which were set up as follows:

- Predictions based on 14 unweighted features with an automatic selection for k between 3 and 9 with 9-fold cross-validation.
- Predictions based on 14 weighted features with an automatic selection for k between 3 and 9 with 9-fold cross-validation.

The optimum value for k is measured against the error calculation for the training and validation sets. The k-value that delivers the lowest error calculation is the best fit for choosing the nearest neighbour in each scenario.

The optimum k for the 14-feature unweighted scenario with an automatic selection between 3 and 9 resulted in 3 nearest neighbours, as illustrated in Figure 7.3, and Table 7.7 shows the error calculations.

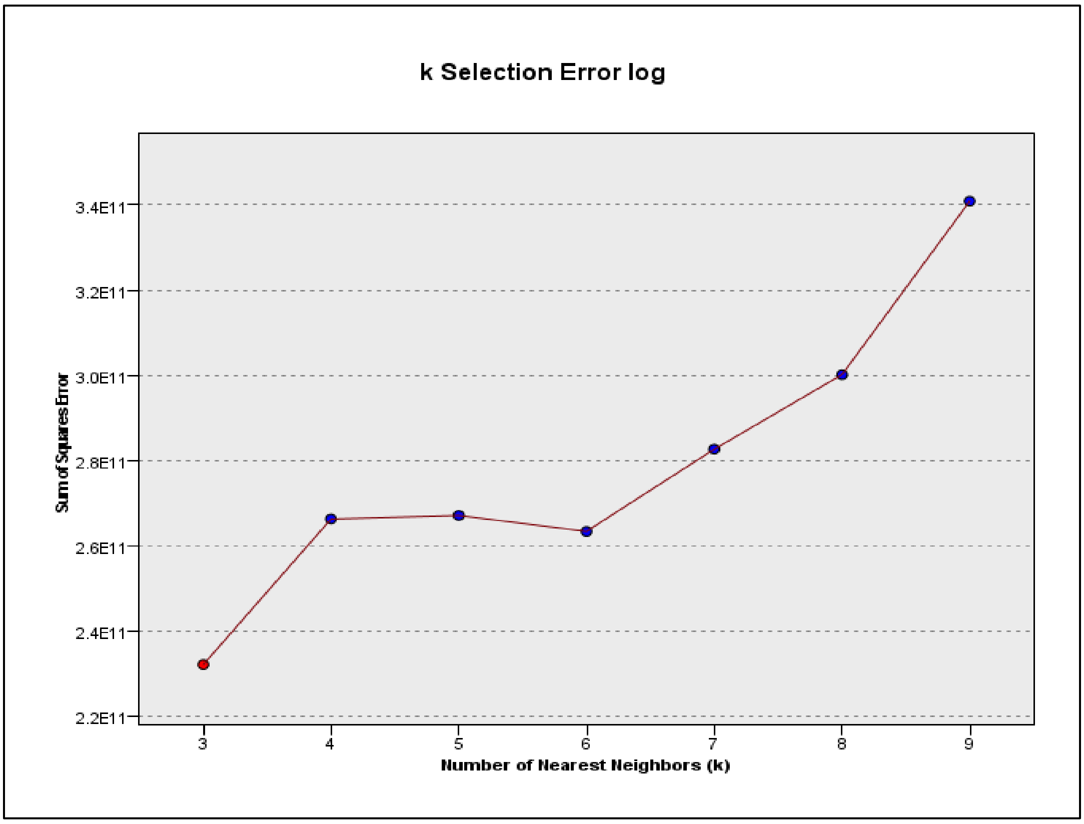

Figure 7.2: Optimum k-selection for the unweighted 14-feature scenario (generated by IBM® SPSS® Statistics)

Table 7.5: Error calculations for the unweighted 14-feature scenario (generated by IBM® SPSS® Statistics)

K	Sum of Squares Error	V3	V4	V5
3	232077519172.724	2.32E11	3	1
4	266276002888.5073	2.66E11	4	0
5	267098062700.03	2.67E11	5	0
6	263370640701.5036	2.63E11	6	0
7	282652188663.9333	2.83E11	7	0
8	300166483741.1154	3.0E11	8	0
9	340906258512.5471	3.41E11	9	0

The optimum k for the 14-feature weighted scenario with an automatic selection between 3 and 9 also resulted in 3 nearest neighbours, as illustrated in Figure 7.4, and Table 7.8 shows the error calculations.

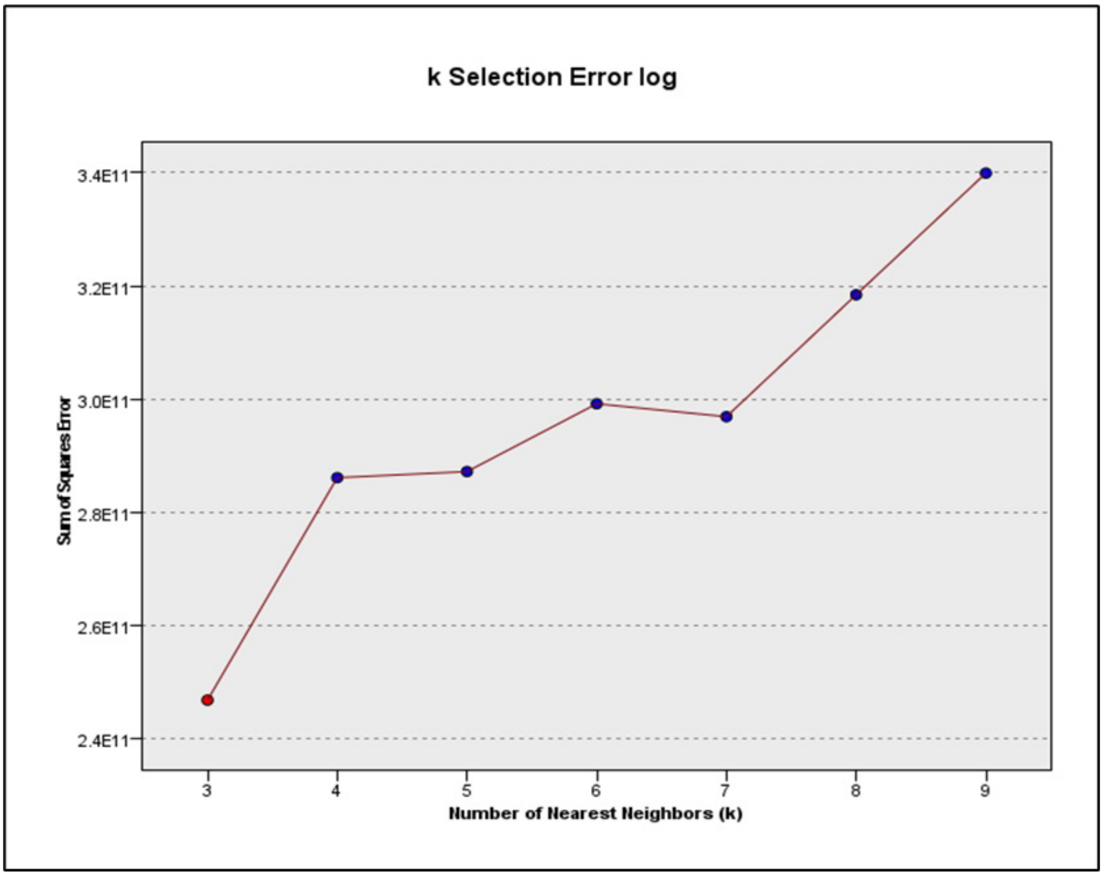

Figure 7.3: Optimum k-selection for the weighted 14-feature scenario

(generated by IBM® SPSS® Statistics)

Table 7.6: Error calculations for the weighted 14-feature scenario (generated by IBM® SPSS® Statistics)

K	Sum of Squares Error	V3	V4	V5
3	246778084994.6507	2.47E11	3	1
4	286092773139.6304	2.86E11	4	0

5	287174895467.3193	2.87E11	5	0
6	299166174479.9319	2.99E11	6	0
7	296881945674.4226	2.97E11	7	0
8	318431945424.0003	3.18E11	8	0
9	339941486865.1852	3.4E11	9	0

7.2.5 Selection of Nearest Neighbours (NN)

The kNN algorithm was previously described as a lazy learner. This is so because this machine learning algorithm does not actually learn from existing data when applied and does not adjust any contained data. This characteristic is precisely why the kNN algorithm is suited for application in this research. Quantity surveyors carry a professional responsibility towards the cost advice given. They would, therefore, not be comfortable with changed cost data without being able to explain the extent of a change. As described in the previous chapter, the selection of the nearest neighbours is simply based on a distance measure that calculates the distance between each of the cases in the dataset and the case to be estimated based on the cases' features.

The nearest neighbours for both scenarios are presented and compared to determine the impact of the feature weighting.

7.2.5.1 Nearest Neighbours for all the cases based on the 14-feature unweighted scenario

Each case in the training set is selected as a focal record, which would be like a new case to be estimated. The predictor space indicates the position of the specific focal point and the selected nearest neighbours. The results display the nearest neighbours and the Euclidean distance from the focal point. The predictor space is shown as a three-dimensional space for illustration purposes, but it is actually a fourteen-dimensional space to accommodate all fourteen features. In several prediction space figures, the focal point is almost hidden because the focal point is obscured by other cases in the foreground. The table for each of the focal points or cases, however, confirms the distances of the selected nearest neighbours.

7.2.5.1.1 Case 1

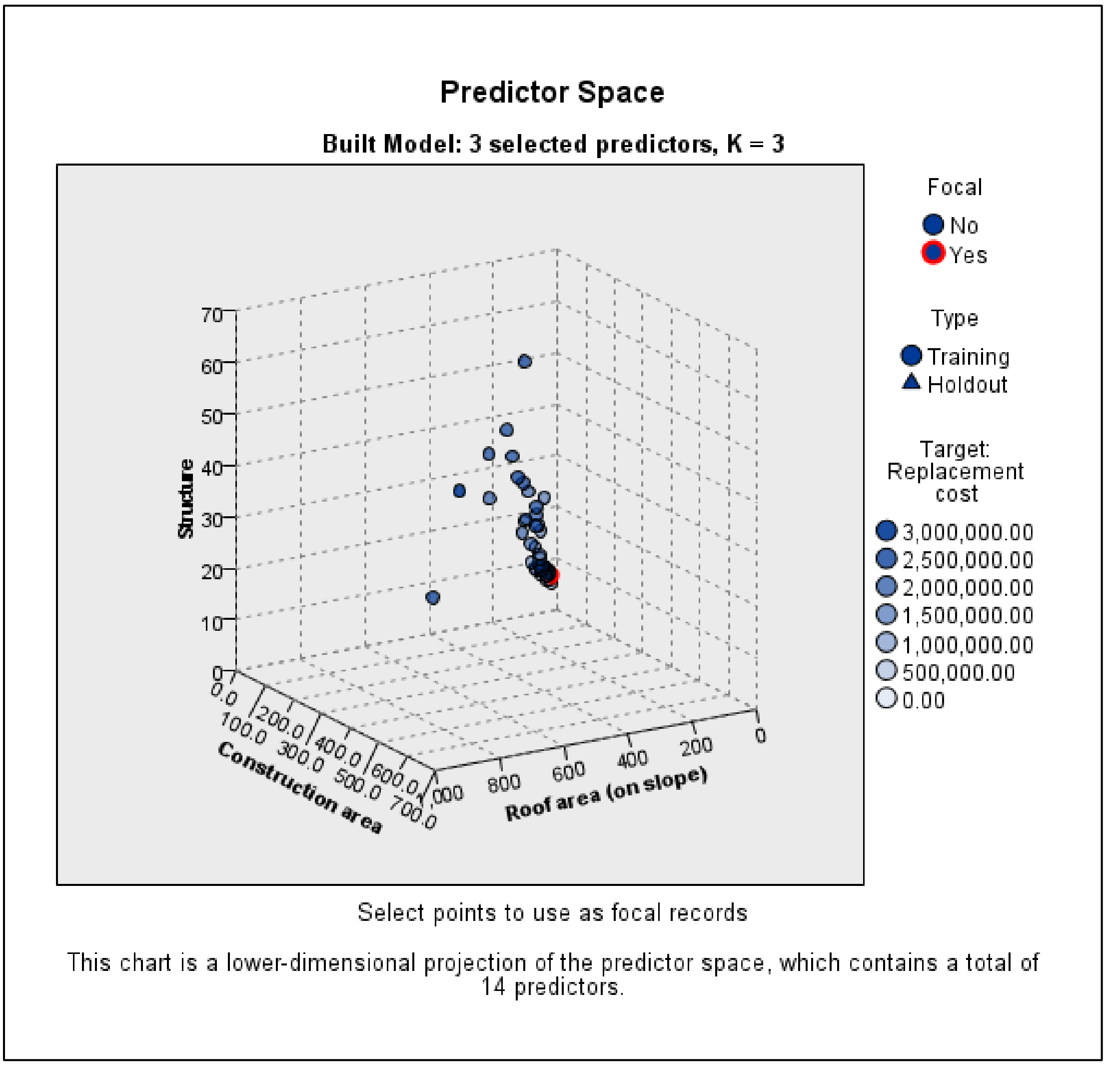

Figure 7.4: Predictor space for case 1 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.7: Nearest neighbours for case 1 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
1	2	3	4	0.306	0.454	0.576

7.2.5.1.2 Case 2

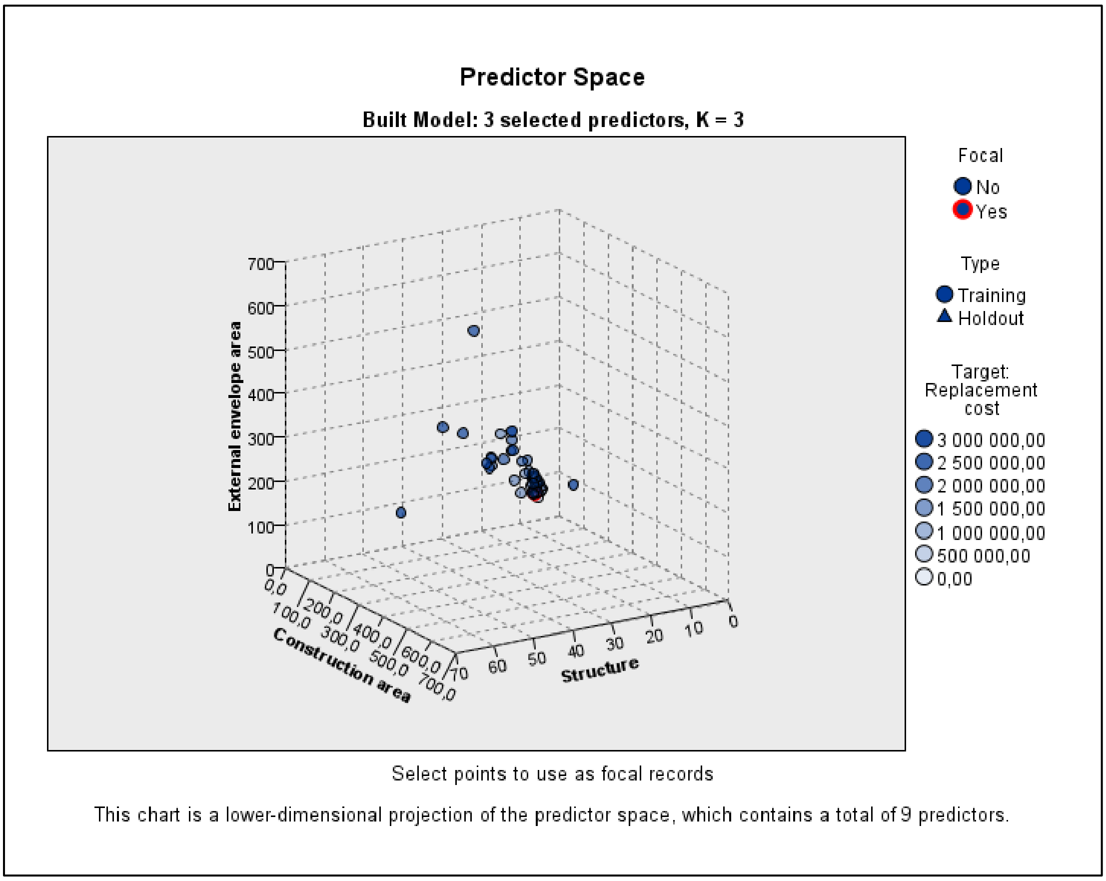

Figure 7.5: Predictor space for case 2 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.8: Nearest neighbours for case 2 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
2	1	3	4	0.306	0.327	0.386

7.2.5.1.3 Case 3

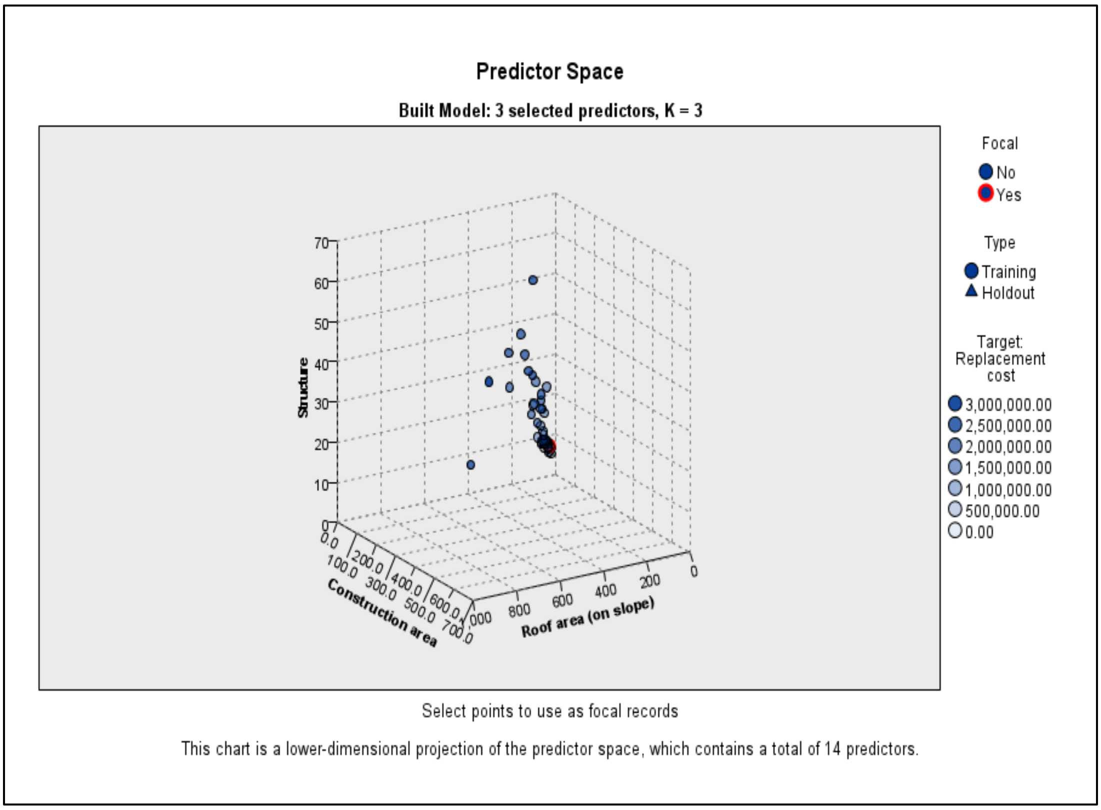

Figure 7.6: Predictor space for case 3 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.9: Nearest neighbours for case 3 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
3	4	2	1	0.202	0.327	0.454

7.2.5.1.4 Case 4

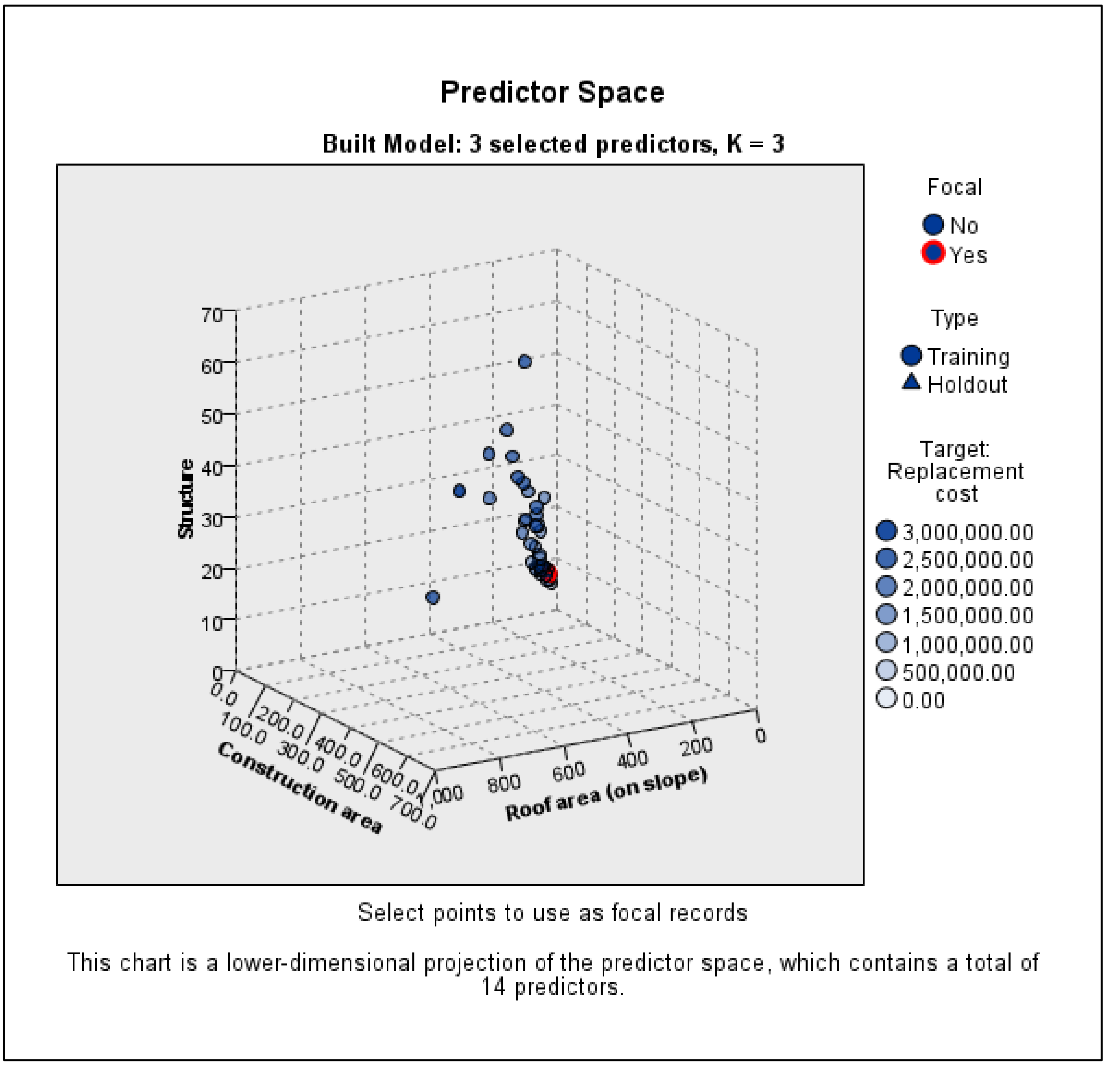

Figure 7.7: Predictor space for case 4 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.10: Nearest neighbours for case 4 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
4	3	5	6	0.202	0.330	0.358

7.2.5.1.5 Case 5

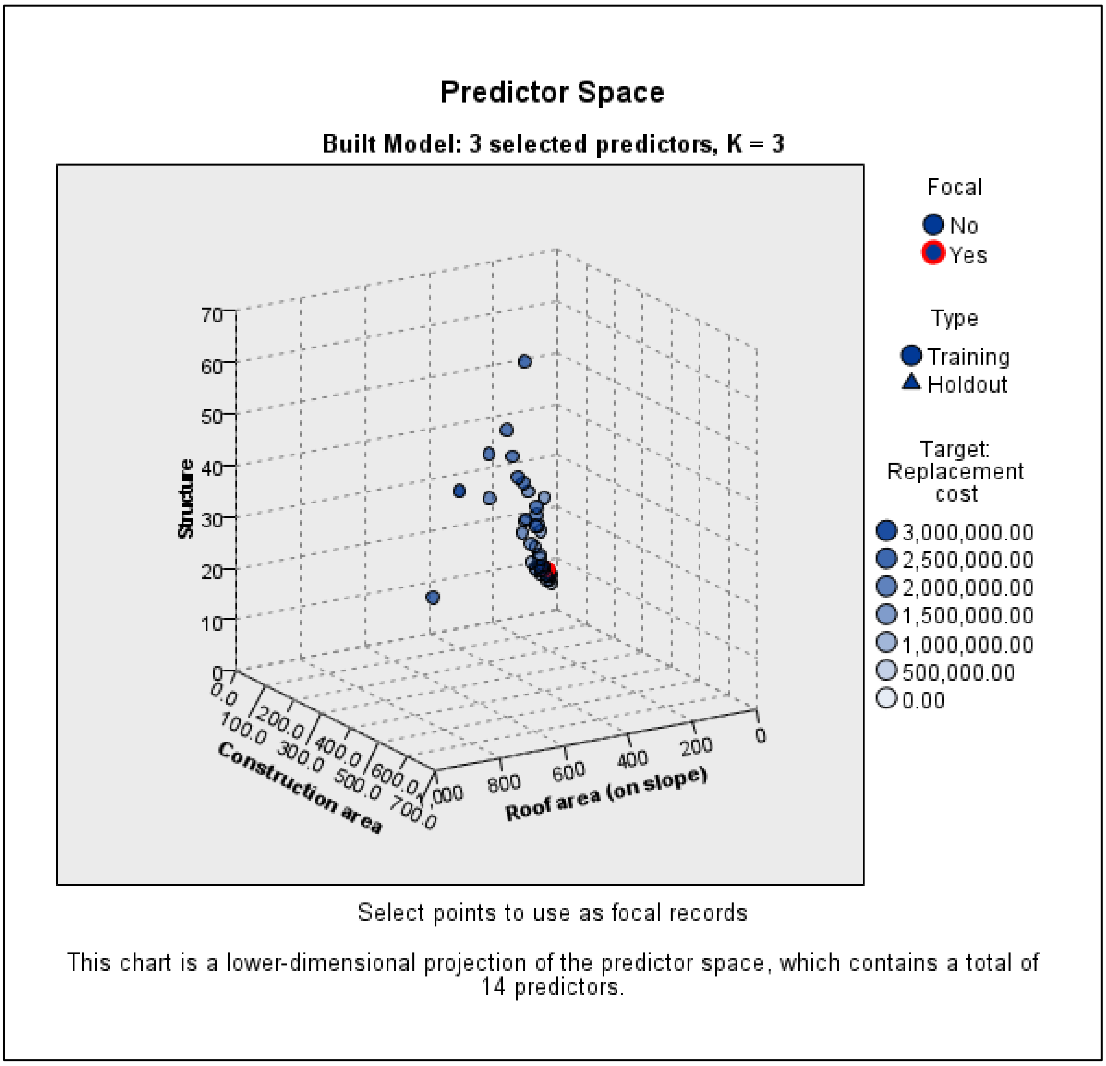

Figure 7.8: Predictor space for case 5 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.11: Nearest neighbours for case 5 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
5	6	4	3	0.107	0.330	0.481

7.2.5.1.6 Case 6

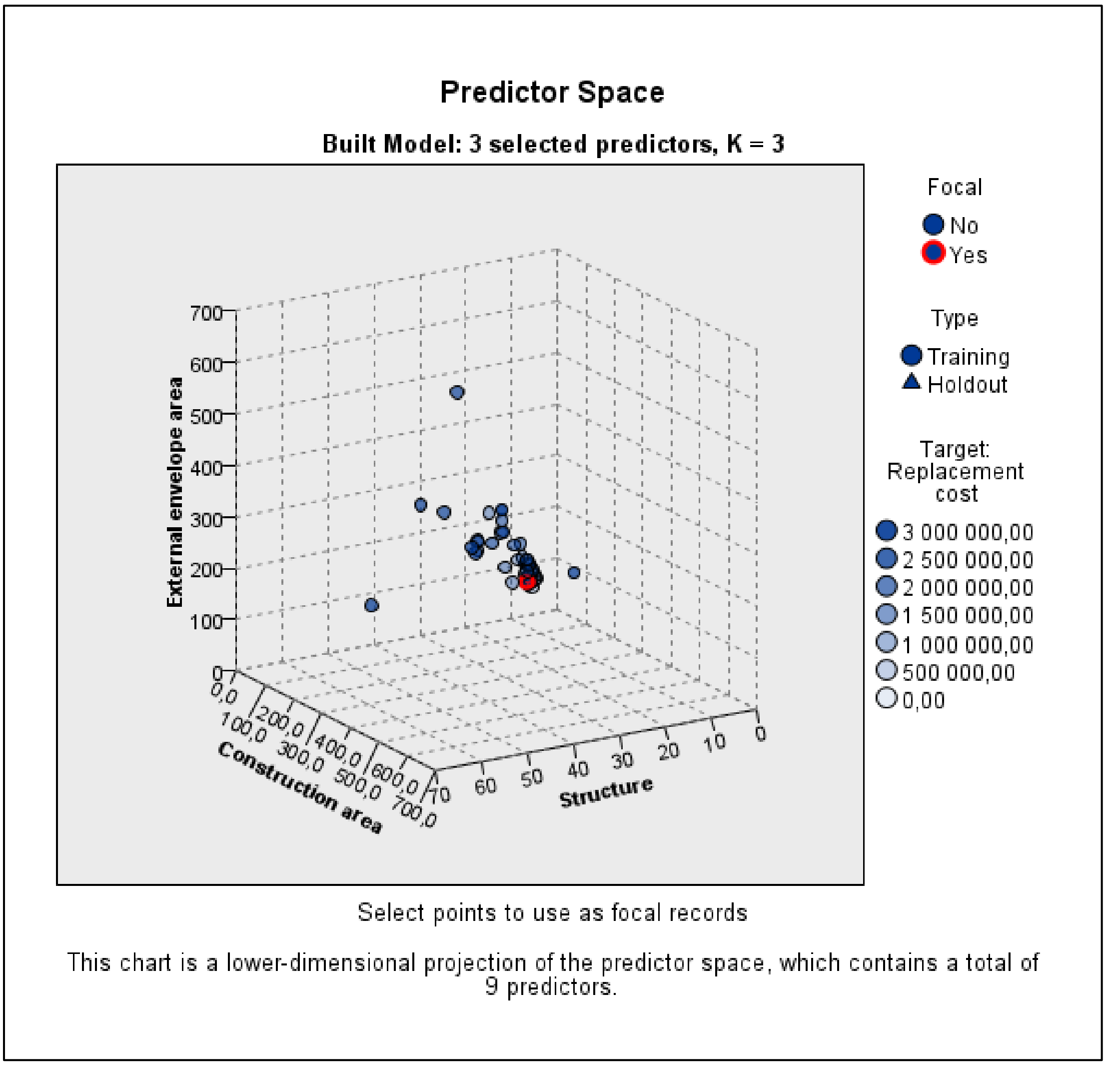

Figure 7.9: Predictor space for case 6 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.12: Nearest neighbours for case 6 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
6	5	4	3	0.107	0.358	0.506

7.2.5.1.7 Case 7

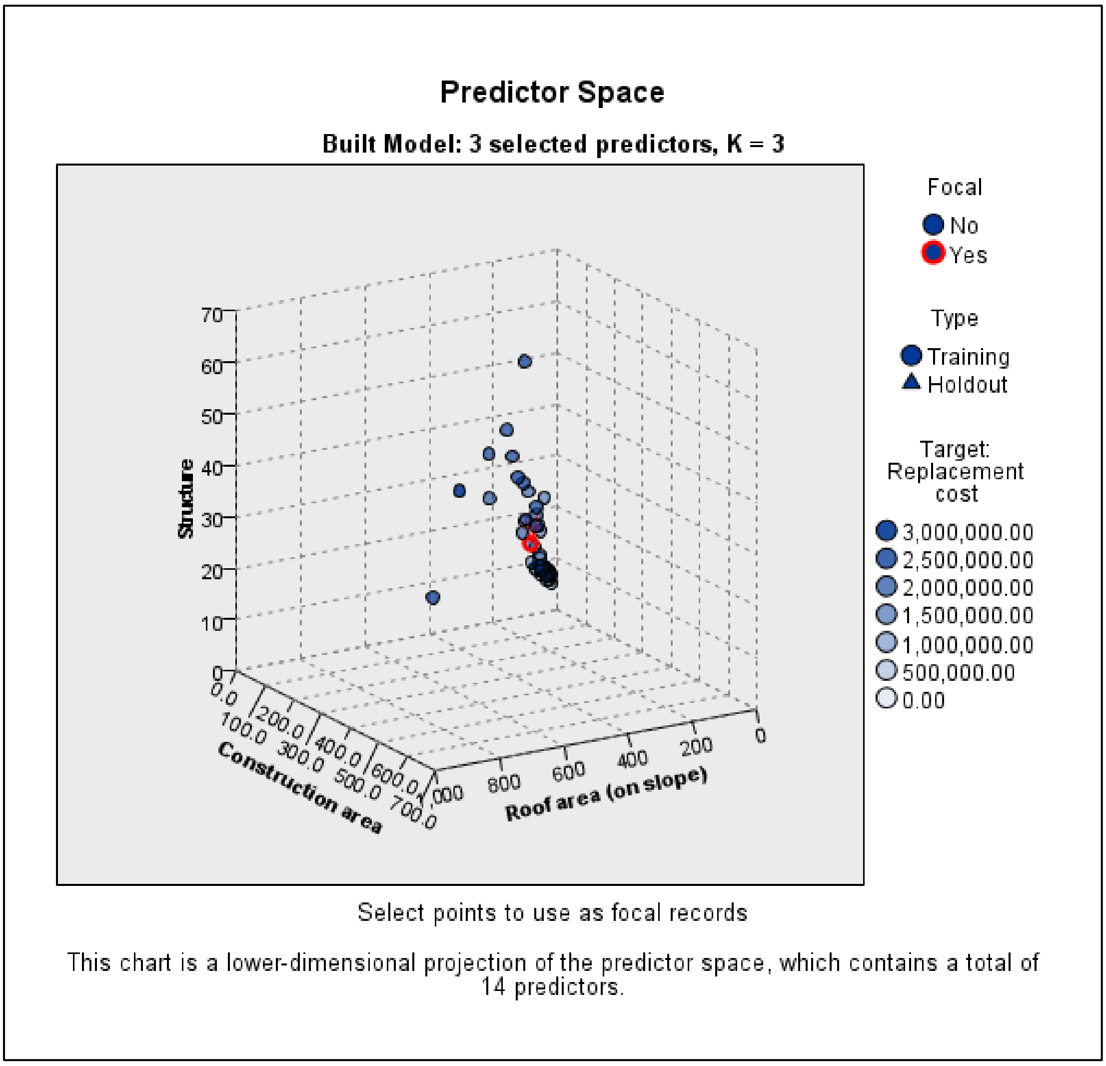

Figure 7.10: Predictor space for case 7 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.13: Nearest neighbours for case 7 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
7	34	21	39	0.894	1.062	1.326

7.2.5.1.8 Case 8

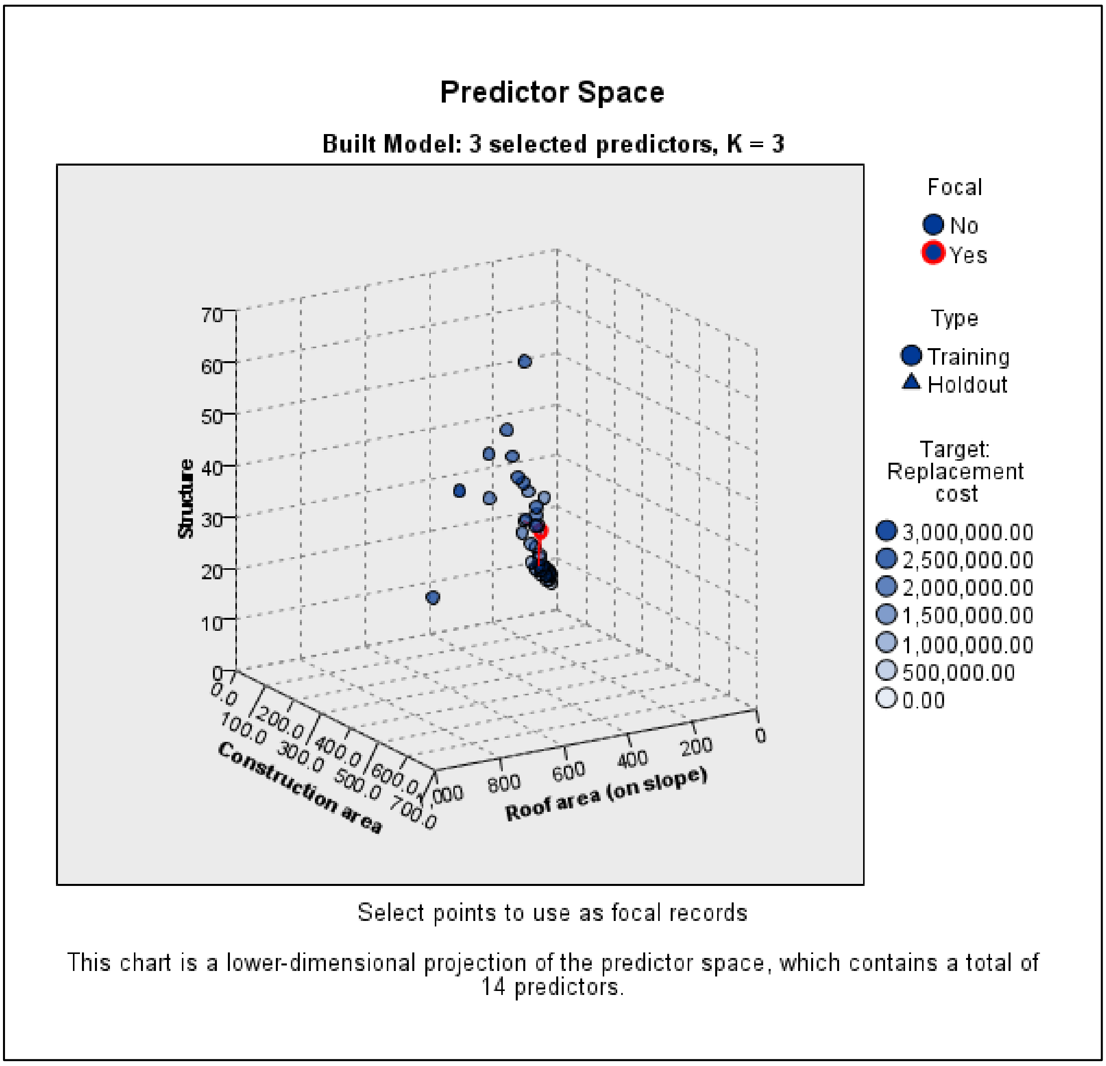

Figure 7.7: Predictor space for case 8 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.14: Nearest neighbours for case 8 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
8	42	32	9	0.858	1.010	1.016

7.2.5.1.9 Case 9

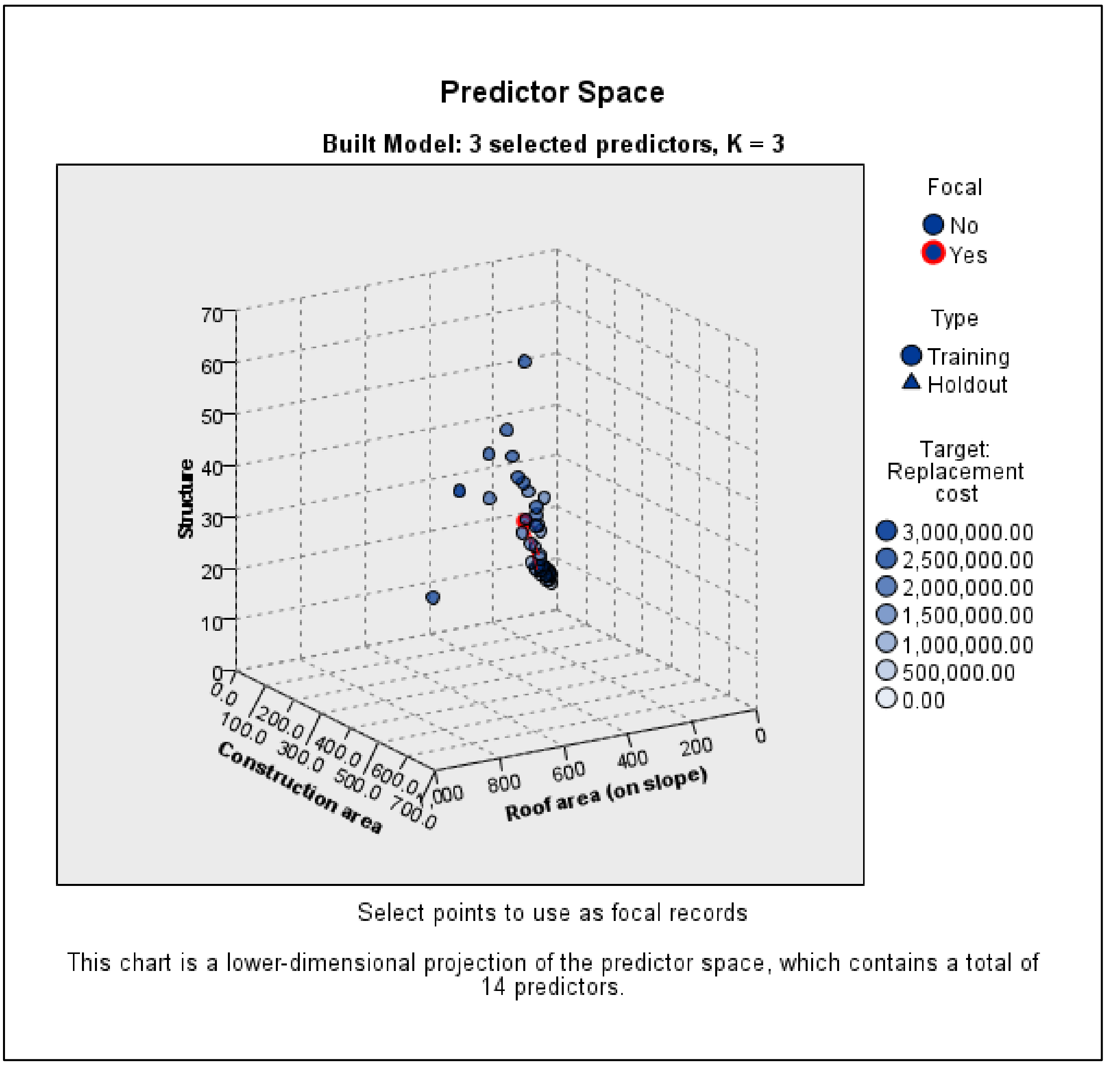

Figure 7.12: Predictor space for case 9 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.15: Nearest neighbours for case 9 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
9	42	8	30	0.786	1.016	1.025

7.2.5.1.10 Case 10

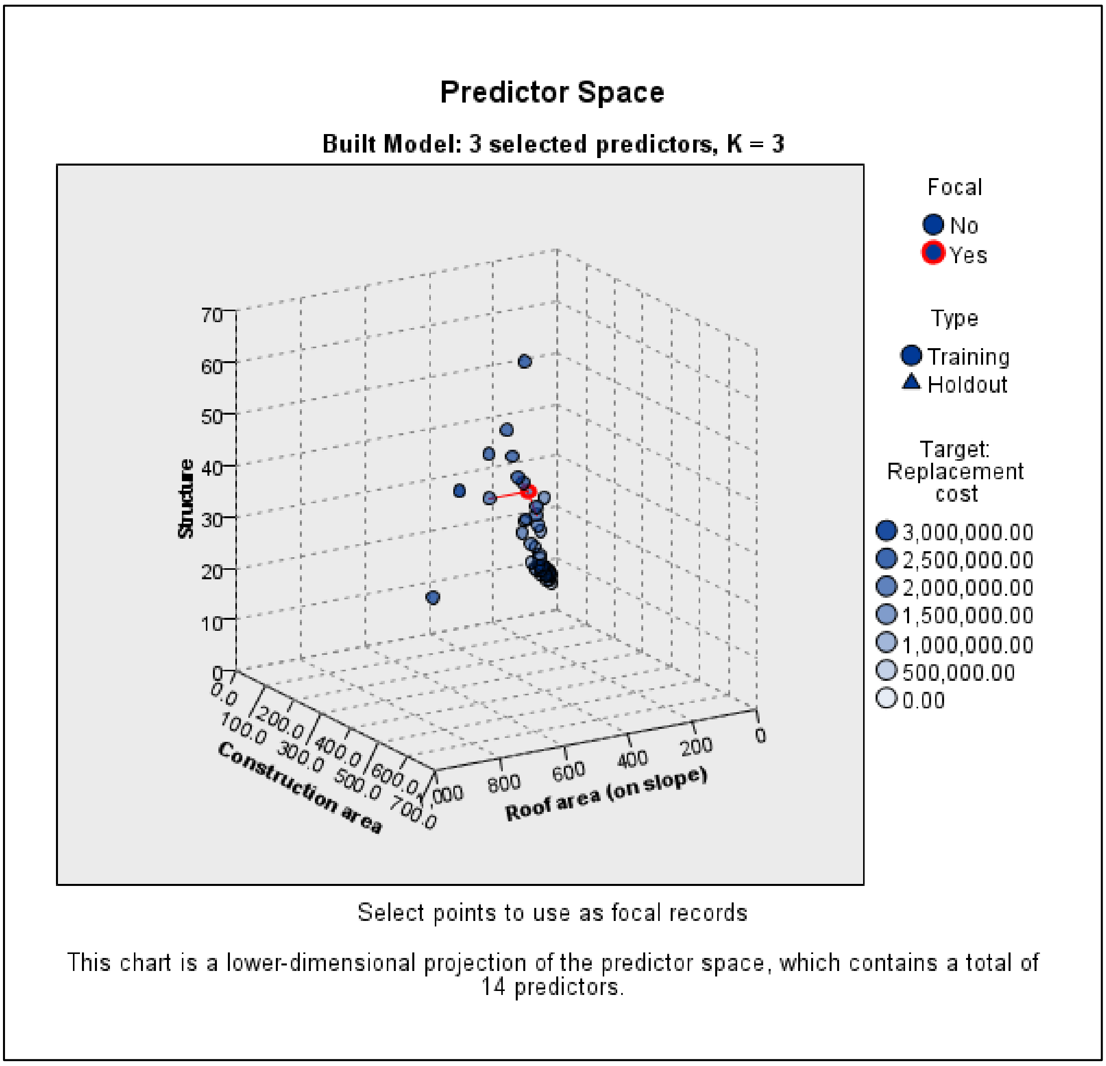

Figure 7.8: Predictor space for case 10 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.16: Nearest neighbours for case 10 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
10	39	20	16	1.285	1.285	1.458

7.2.5.1.11 Case 11

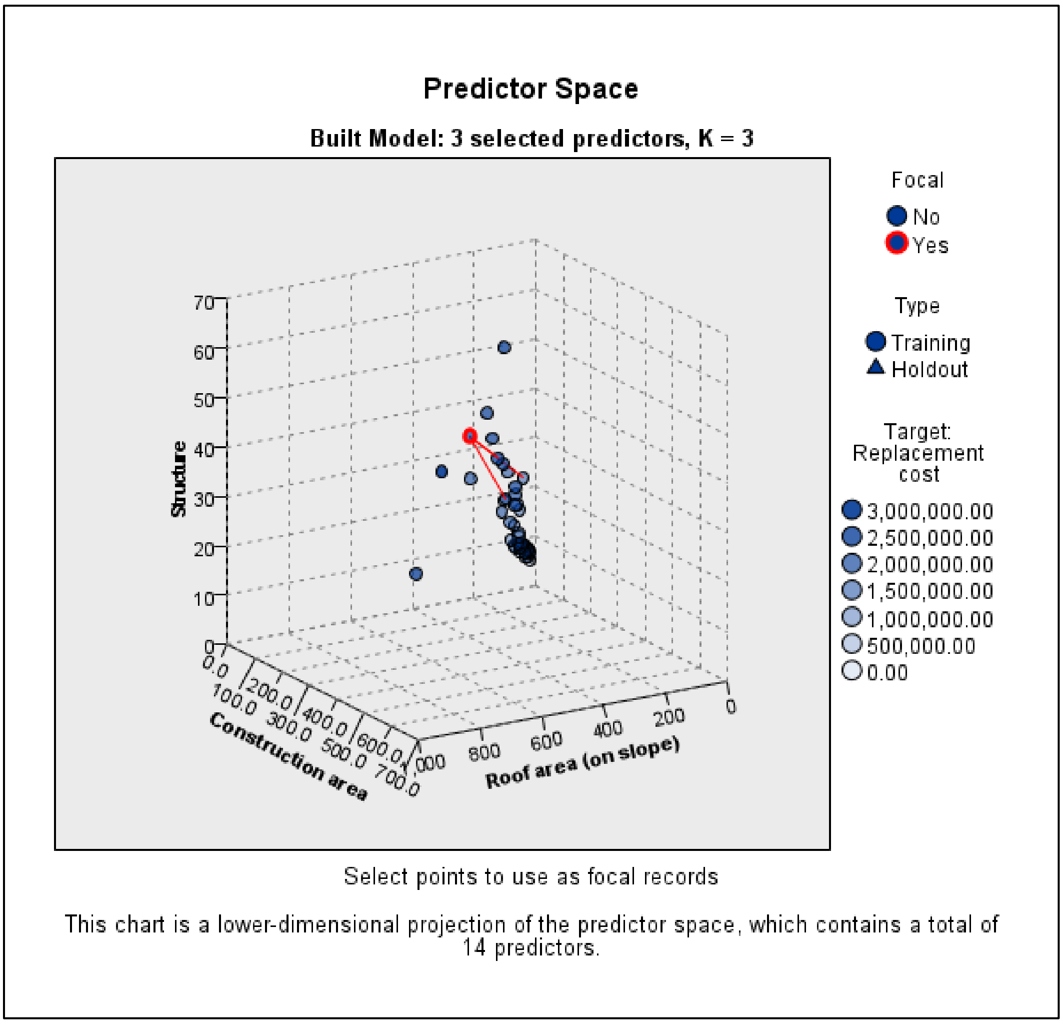

Figure 7.9: Predictor space for case 11 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.17: Nearest neighbours for case 11 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
11	16	14	34	1.352	1.689	1.691

7.2.5.1.12 Case 12

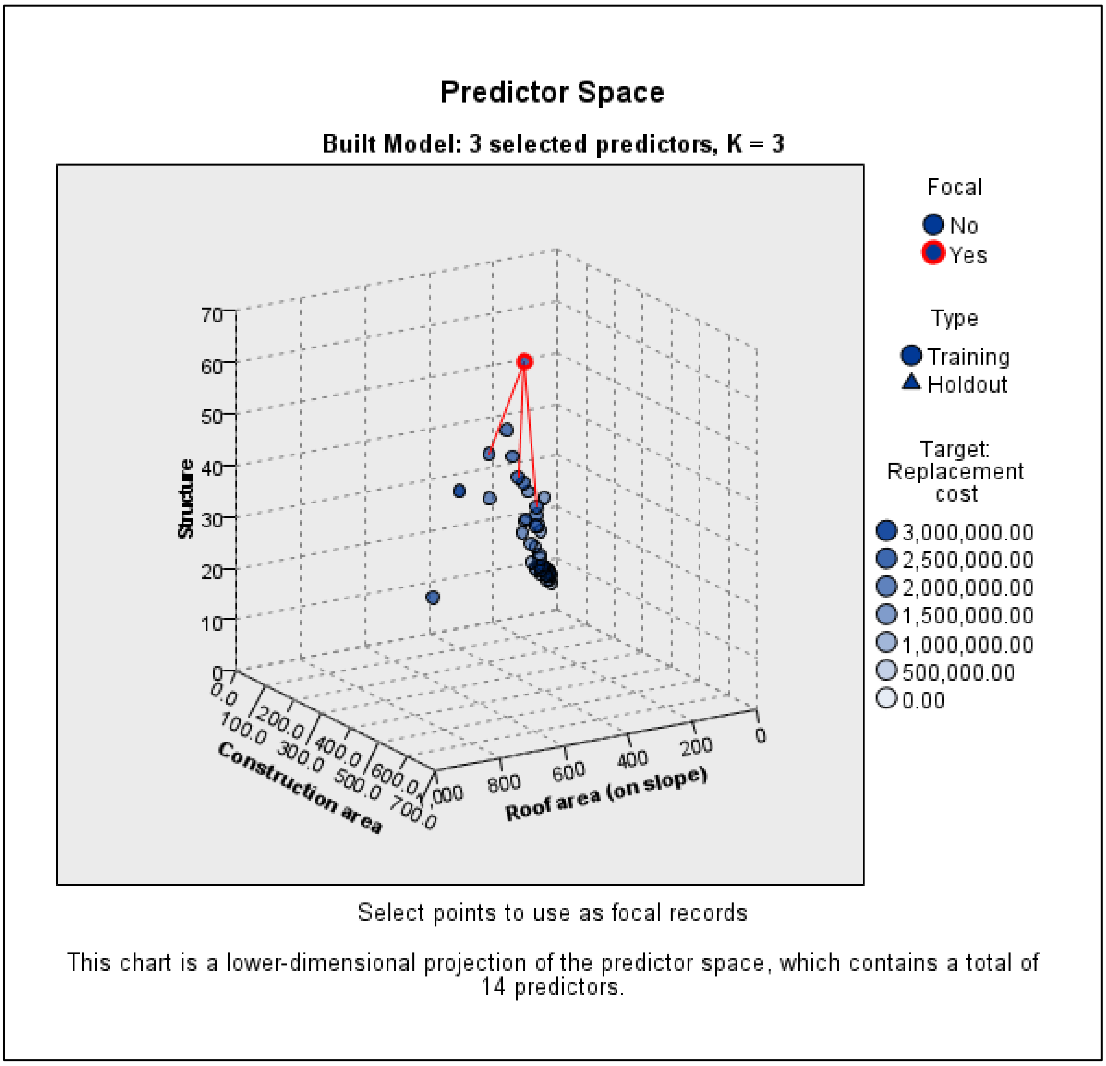

Figure 7.10: Predictor space for case 12 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.18: Nearest neighbours for case 12 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
12	11	16	13	1.751	1.916	2.214

7.2.5.1.13 Case 13

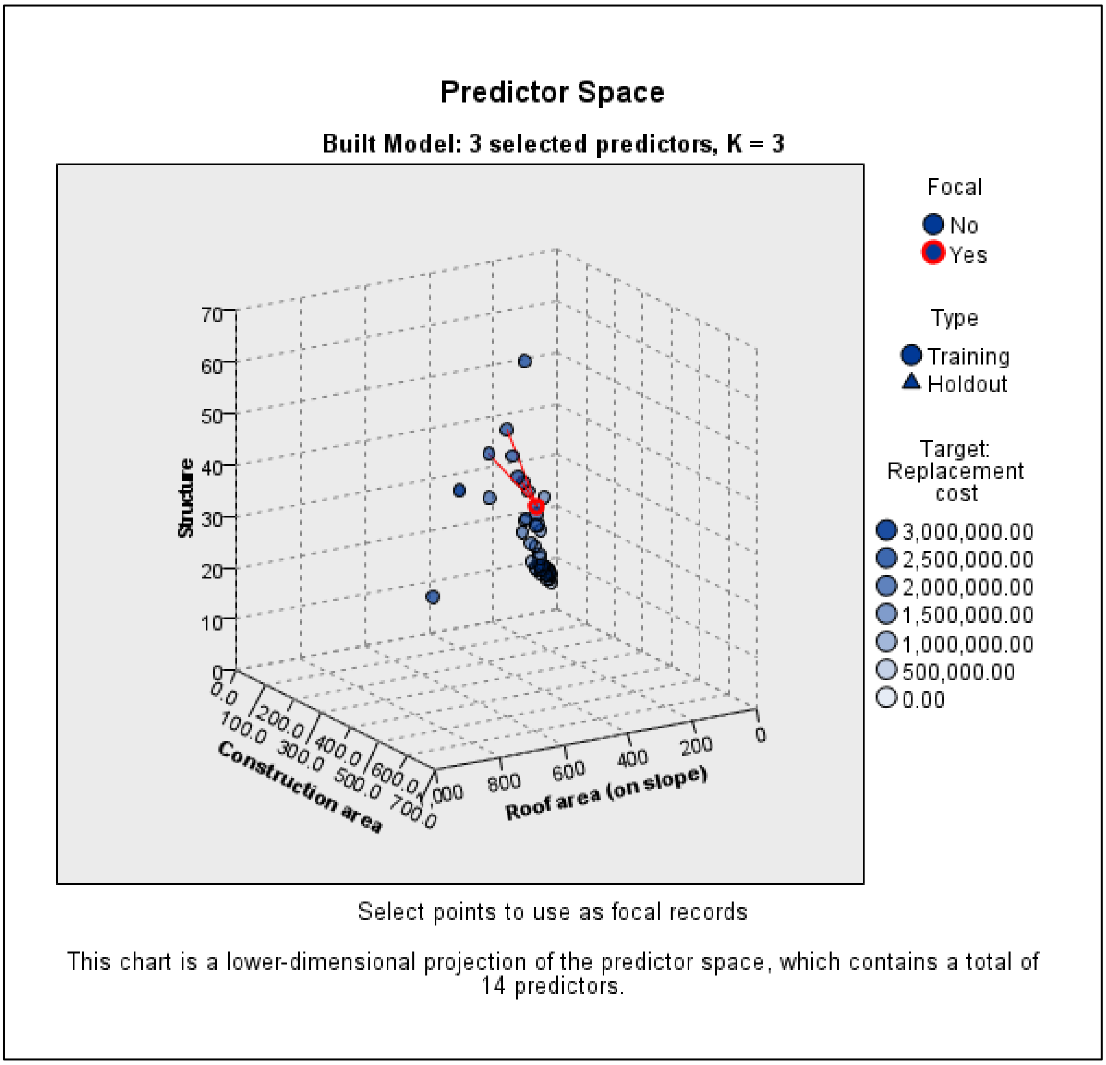

Figure 7.11: Predictor space for case 13 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.19: Nearest neighbours for case 13 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
13	16	19	11	1.737	1.855	2.106

7.2.5.1.14 Case 14

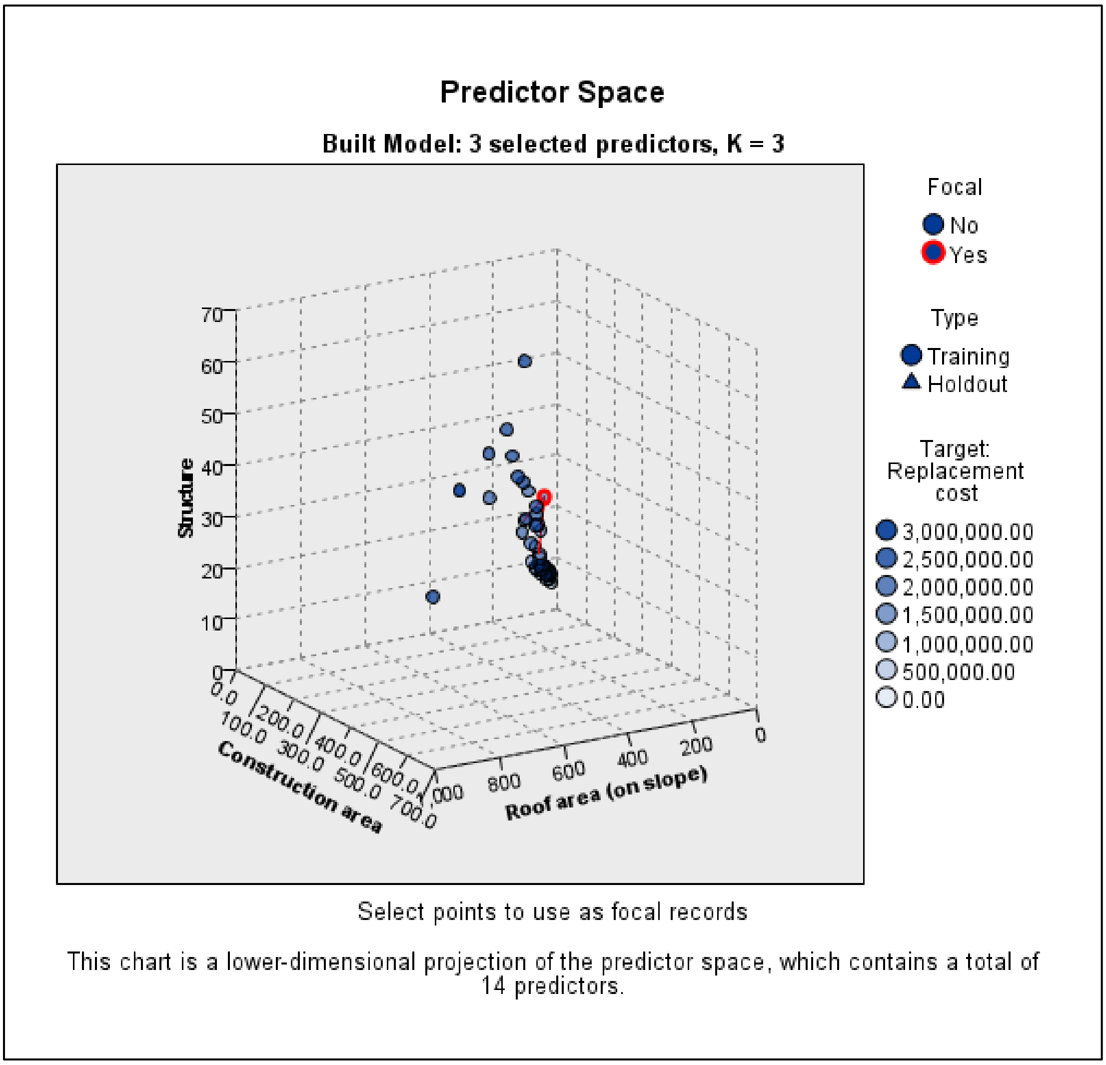

Figure 7.12: Predictor space for case 14 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.20: Nearest neighbours for case 14 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
14	9	8	42	1.258	1.269	1.380

7.2.5.1.15 Case 15

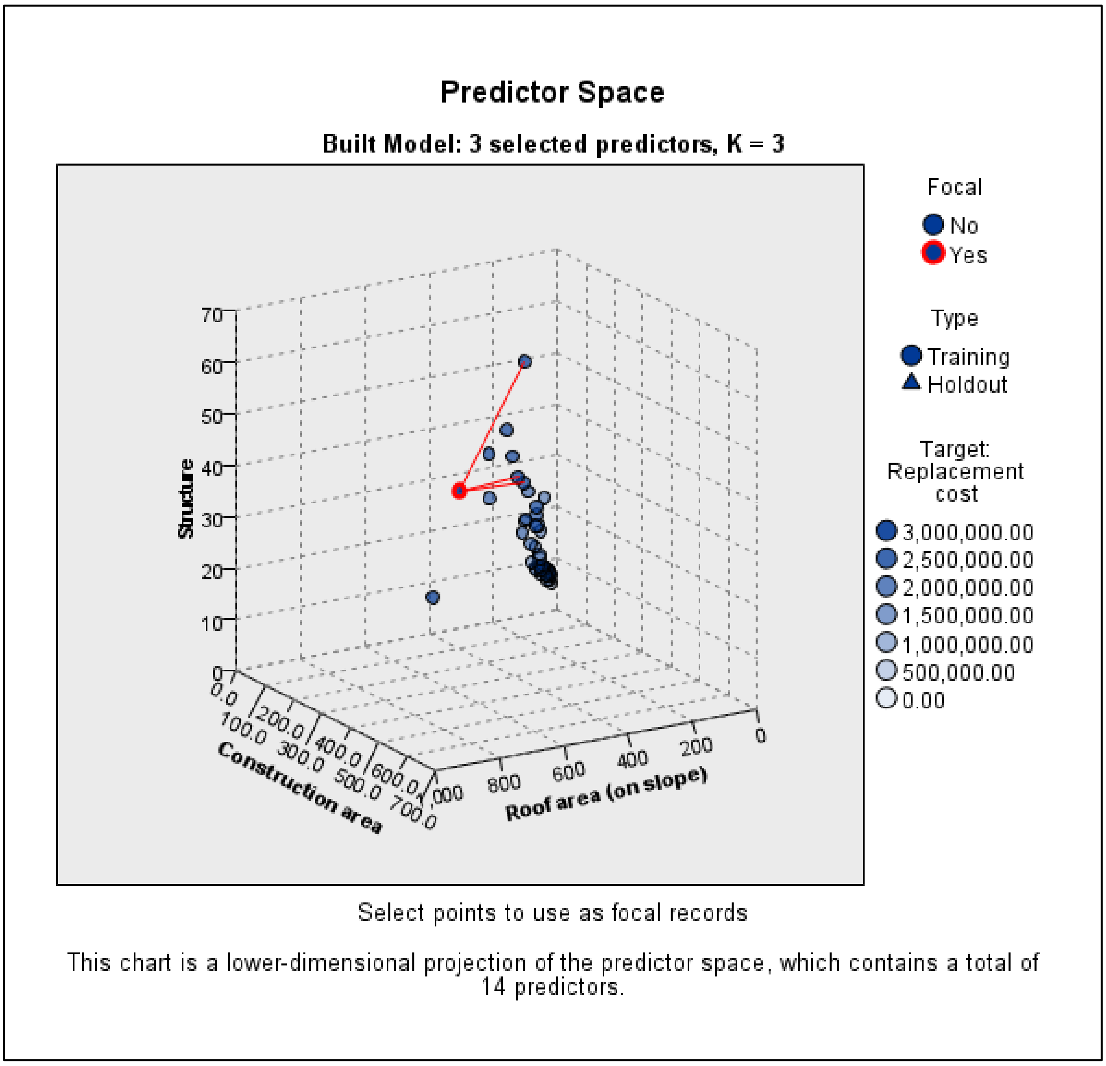

Figure 7.13: Predictor space for case 15 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.21: Nearest neighbours for case 15 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
15	22	12	16	1.919	2.238	2.601

7.2.5.1.16 Case 16

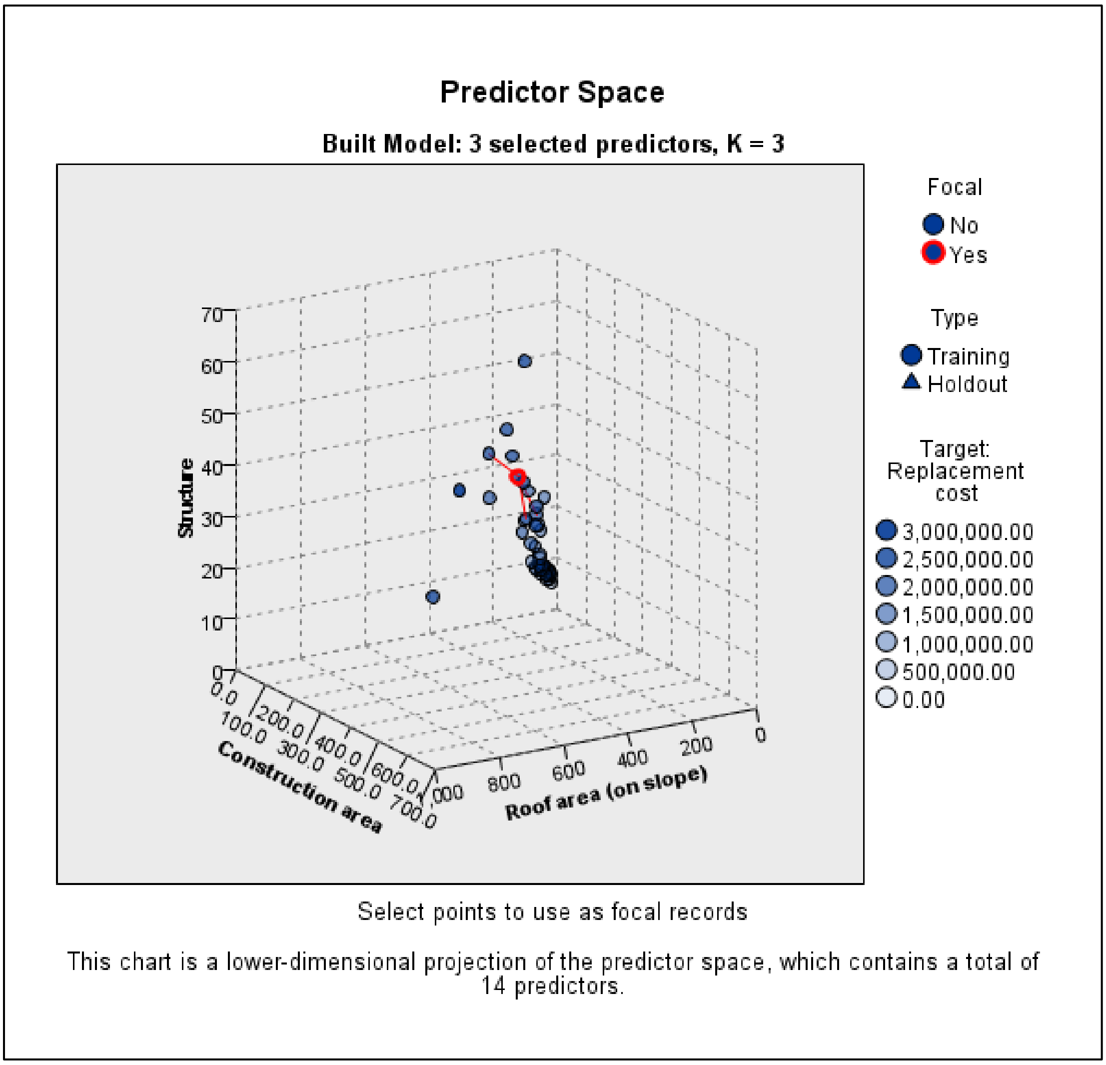

Figure 7.14: Predictor space for case 16 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.22: Nearest neighbours for case 16 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
16	34	11	39	1.303	1.352	1.384

7.2.5.1.17 Case 17

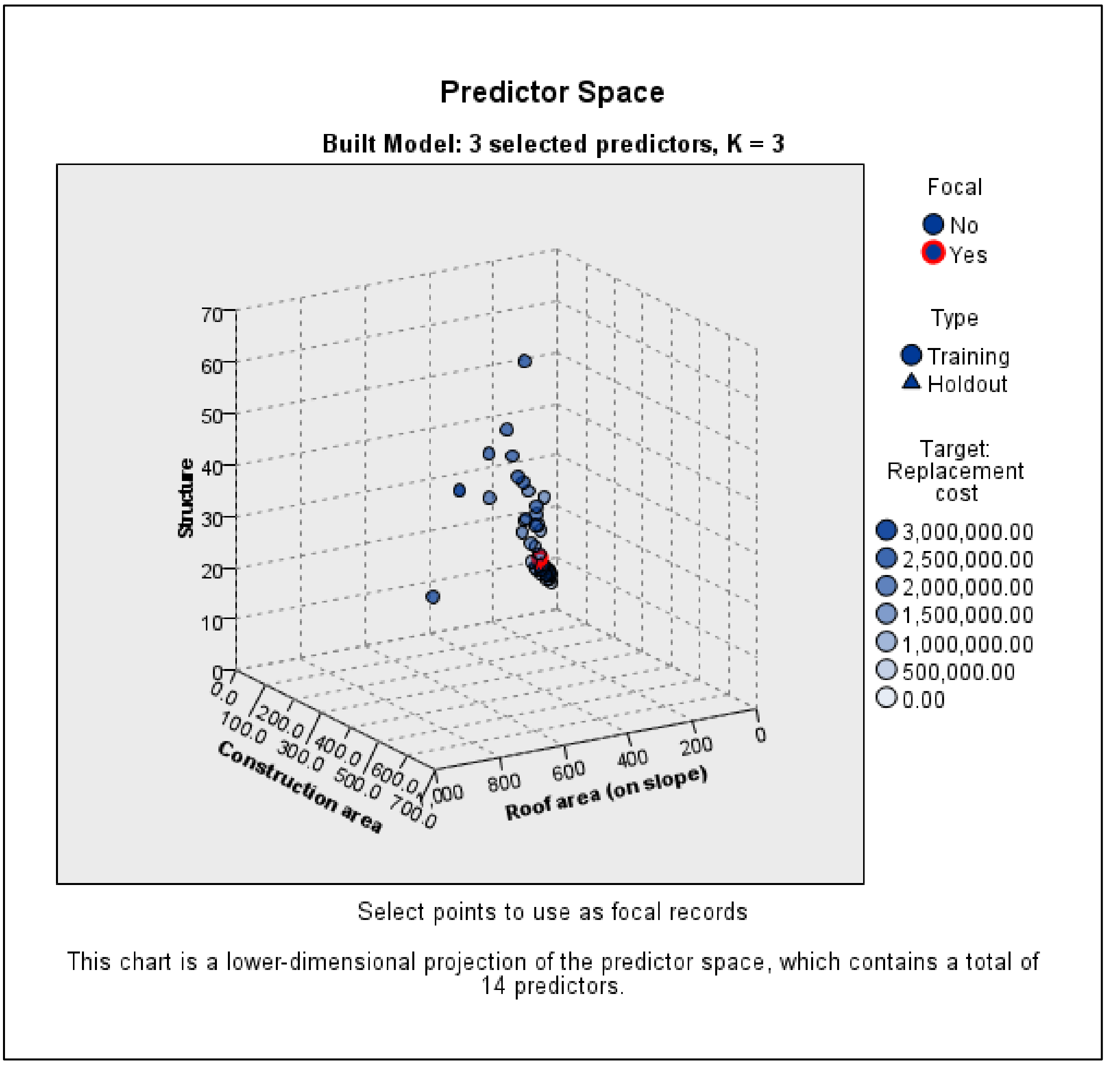

Figure 7.20: Predictor space for case 17 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.23: Nearest neighbours for case 17 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
17	31	30	28	0.624	0.671	0.695

7.2.5.1.18 Case 18

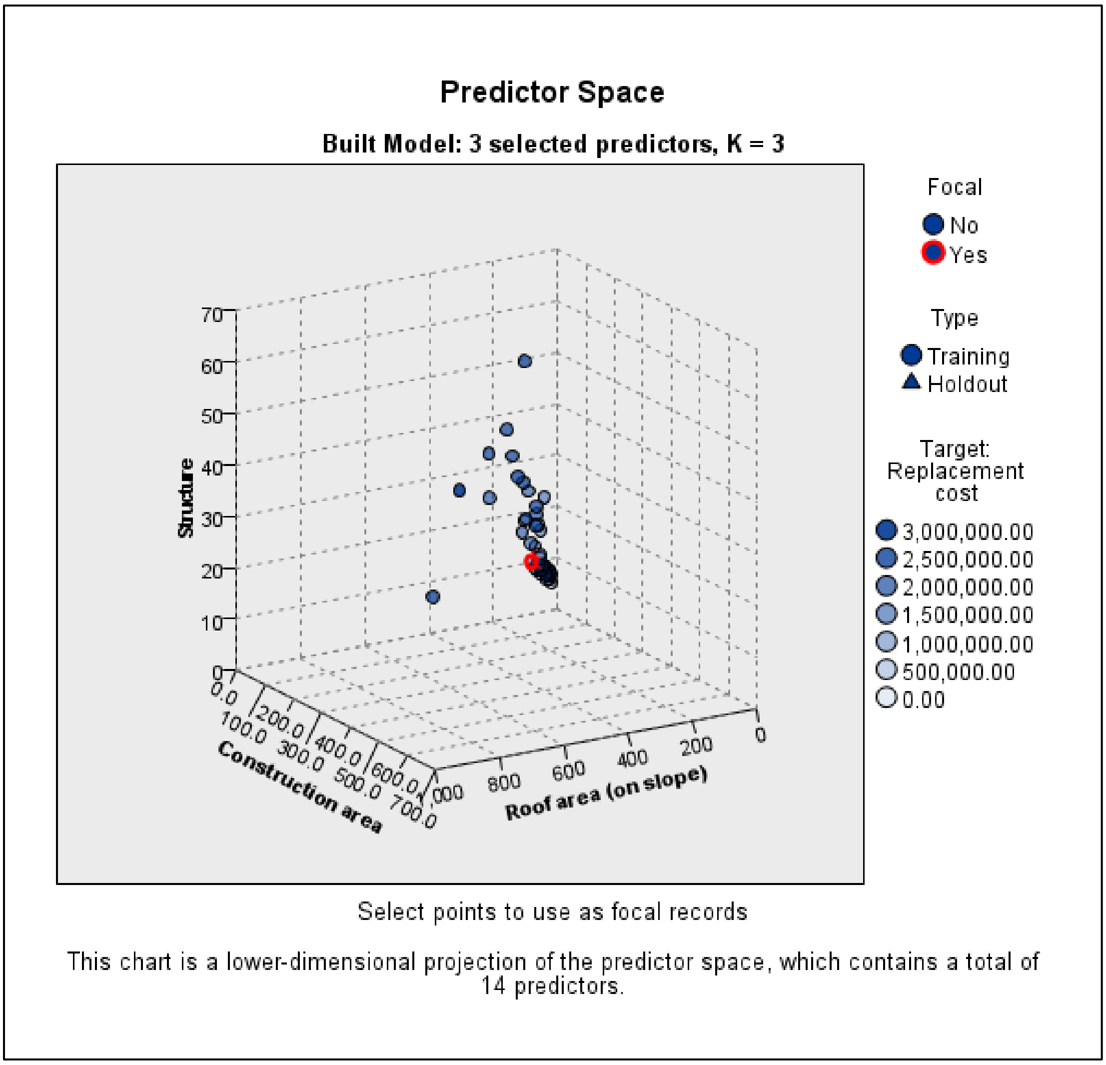

Figure 7.15: Predictor space for case 18 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.24: Nearest neighbours for case 18 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbors			Nearest Distances		
	1	2	3	1	2	3
18	17	33	31	1.089	1.227	1.488

7.2.5.1.19 Case 19

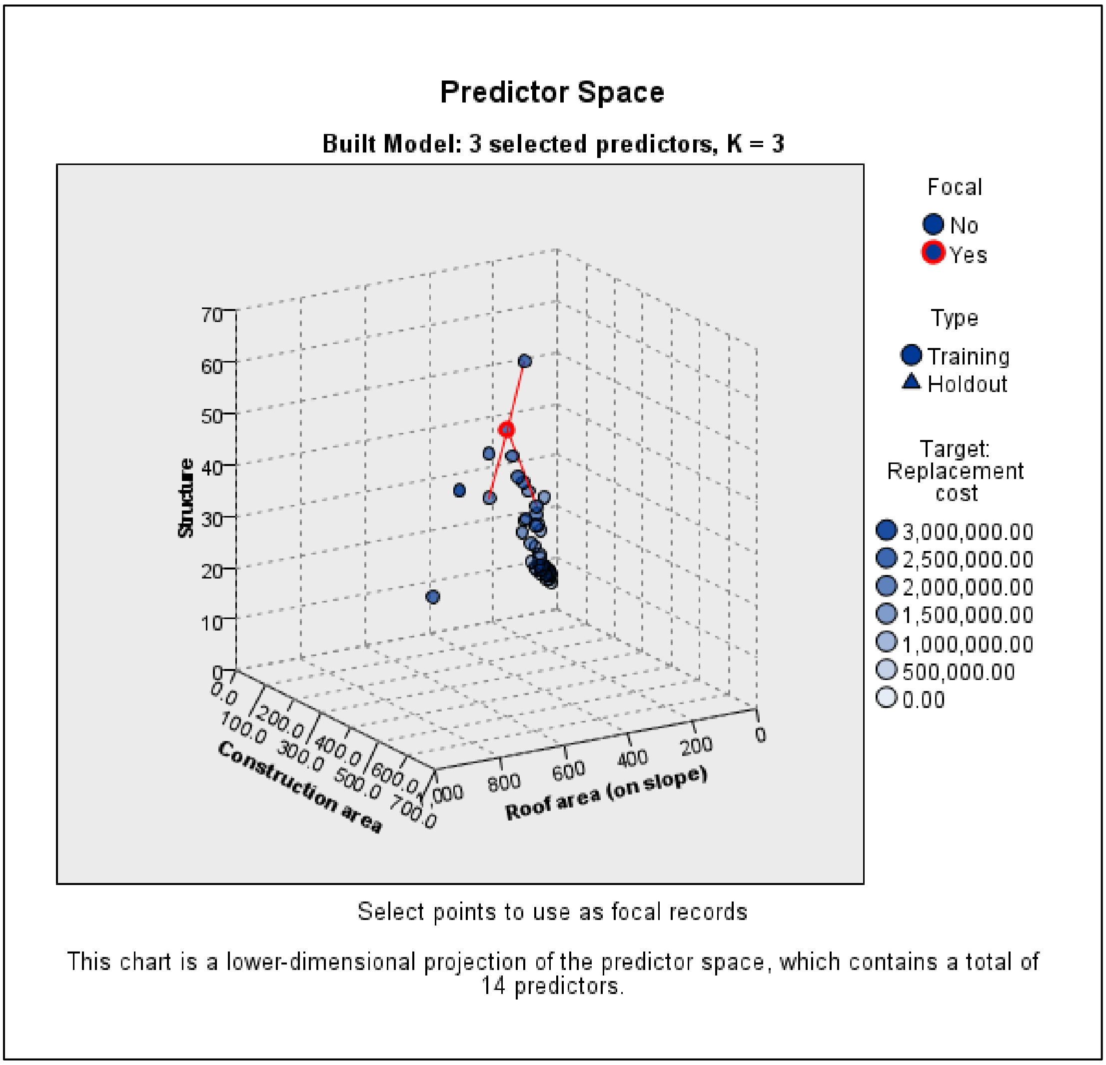

Figure 7.16: Predictor space for case 19 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.25: Nearest neighbours for case 19 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
19	13	12	20	1.855	2.229	2.276

7.2.5.1.20 Case 20

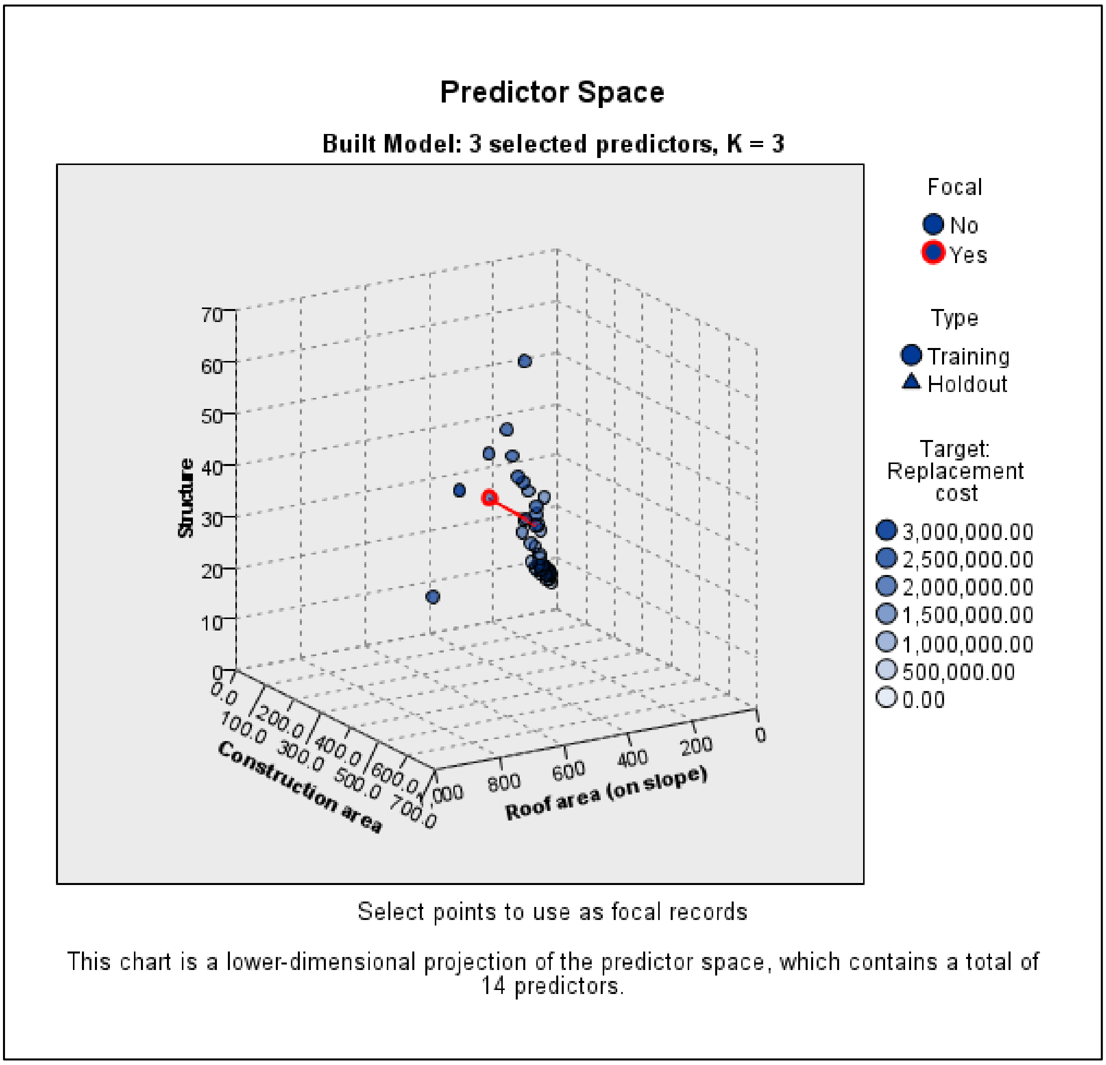

Figure 7.17: Predictor space for case 20 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.26: Nearest neighbours for case 20 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
20	21	34	10	1.186	1.262	1.285

7.2.5.1.21 Case 21

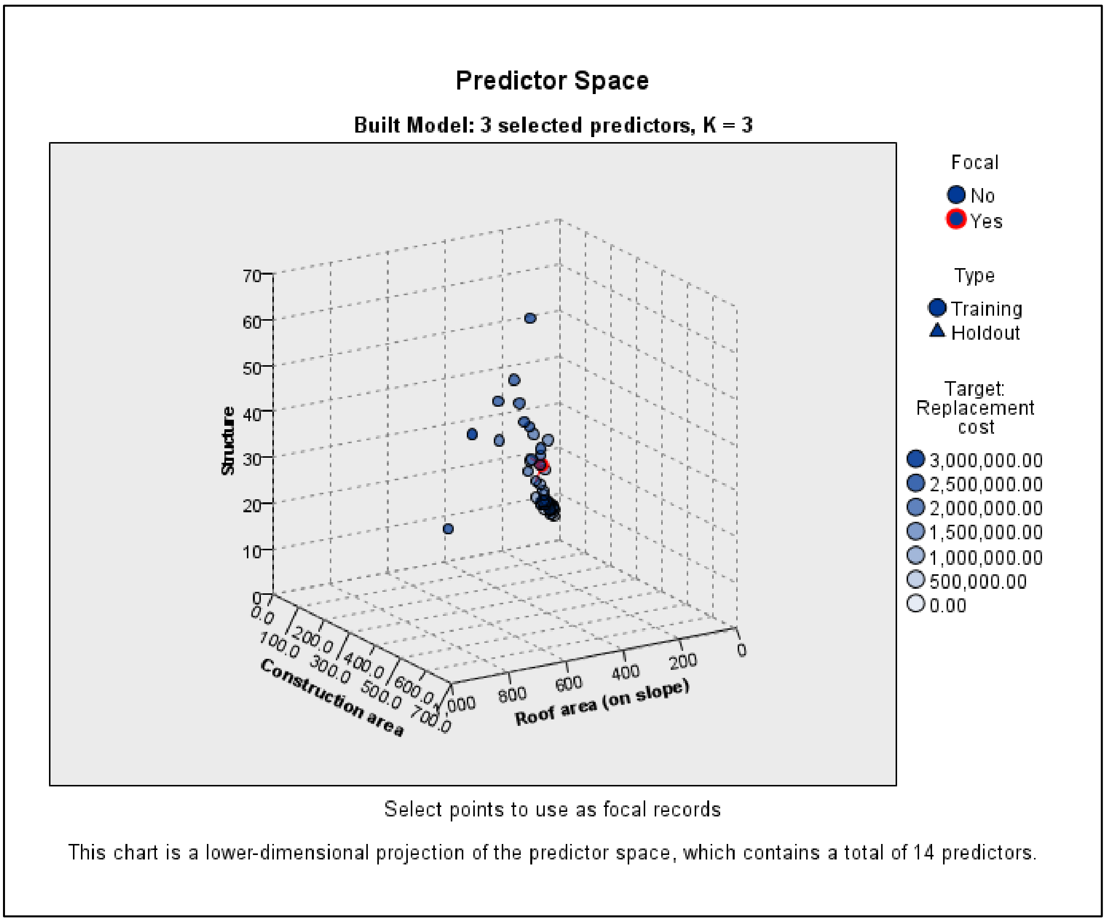

Figure 7.18: Predictor space for case 21 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.27: Nearest neighbours for case 21 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
21	7	8	34	1.062	1.083	1.170

7.2.5.1.22 Case 22

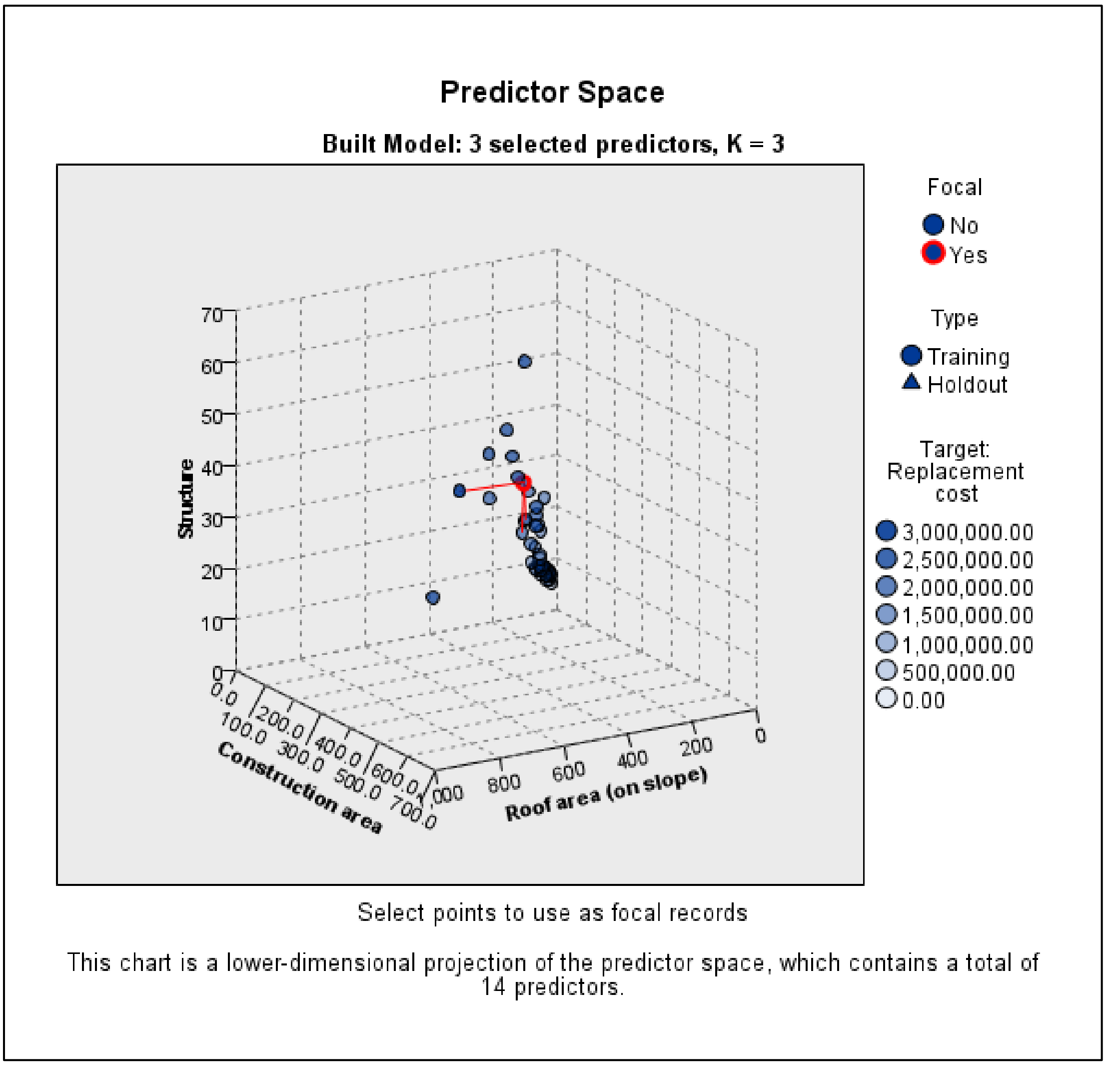

Figure 7.19: Predictor space for case 22 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.28: Nearest neighbours for case 22 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
22	41	15	34	1.591	1.919	1.995

7.2.5.1.23 Case 23

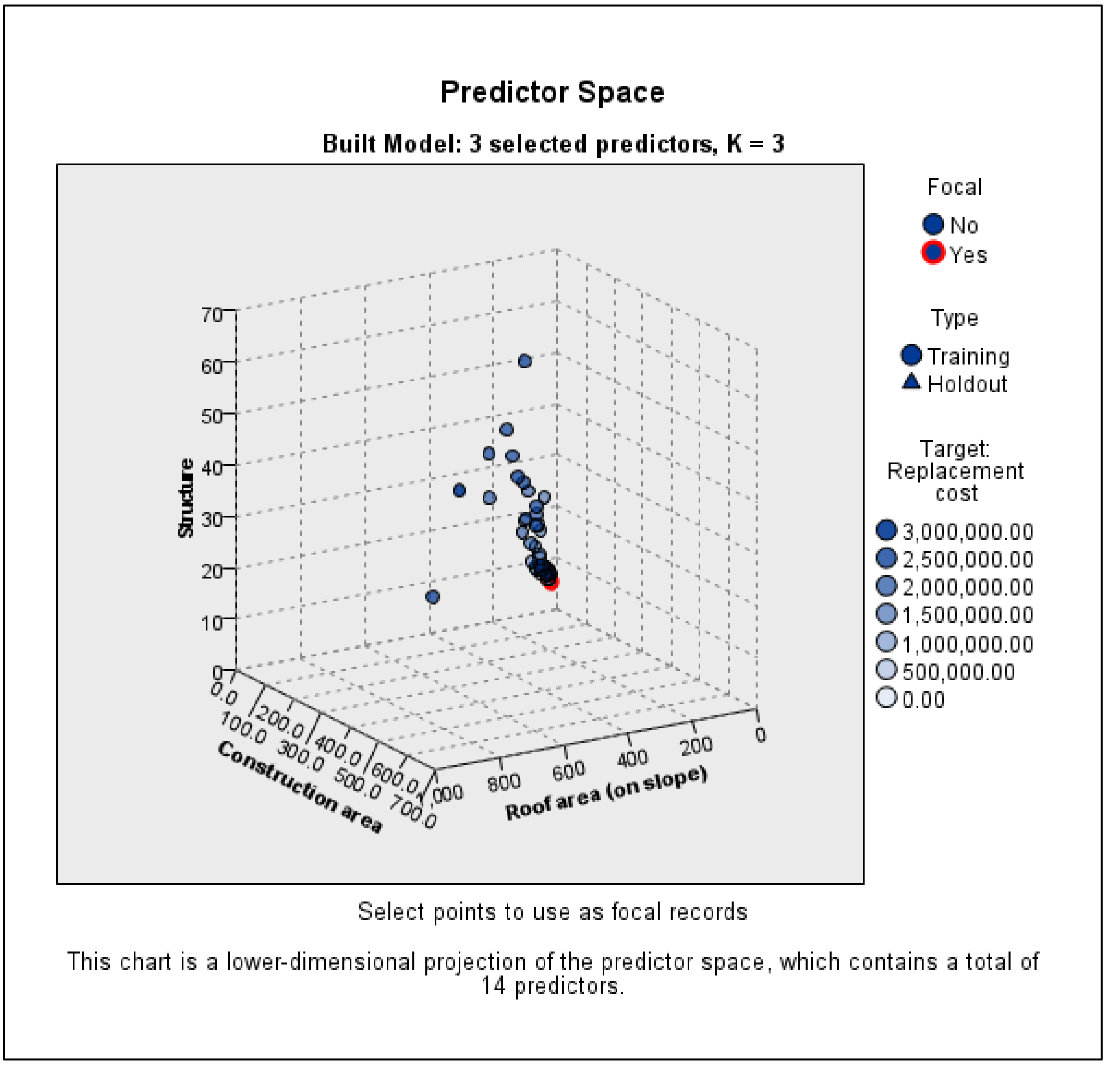

Figure 7.20: Predictor space for case 23 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.29: Nearest neighbours for case 23 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
23	24	43	36	0.092	0.343	0.450

7.2.5.1.24 Case 24

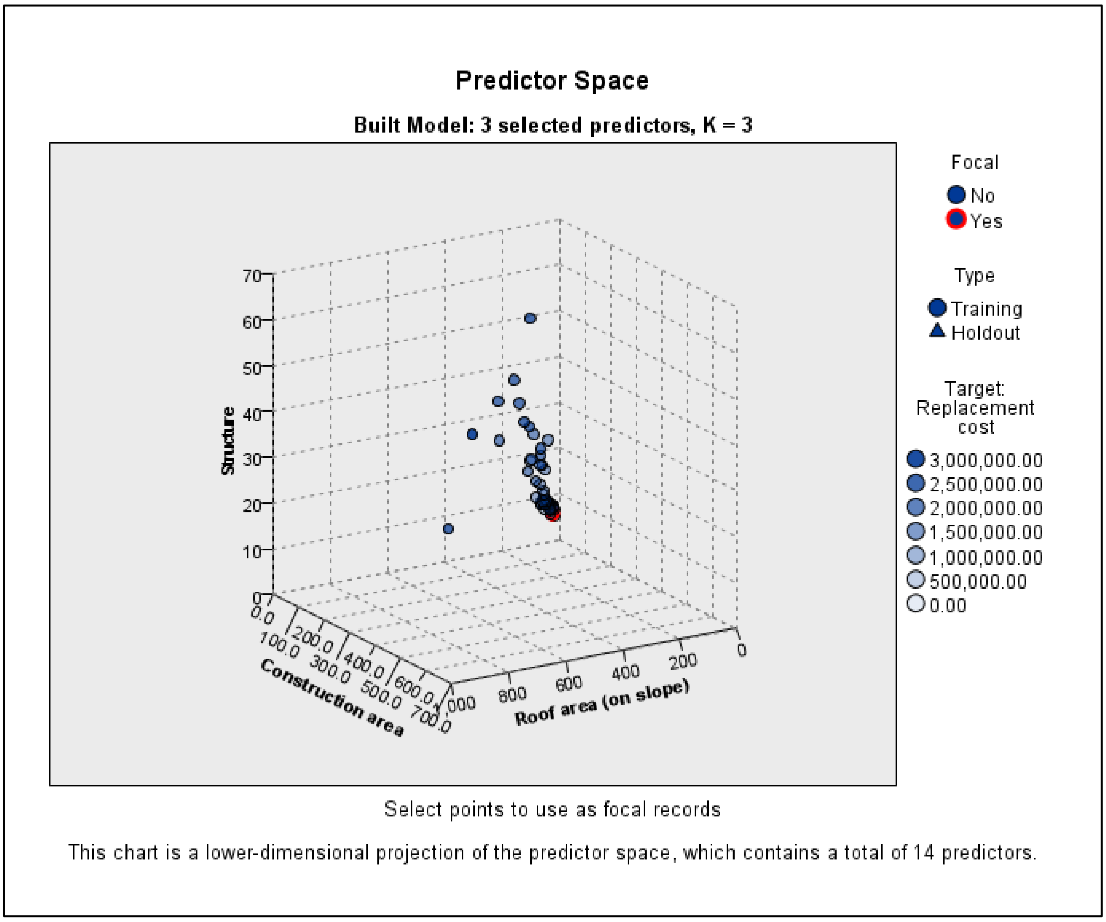

Figure 7.21: Predictor space for case 24 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.30: Nearest neighbours for case 24 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
24	23	43	36	0.092	0.358	0.391

7.2.5.1.25 Case 25

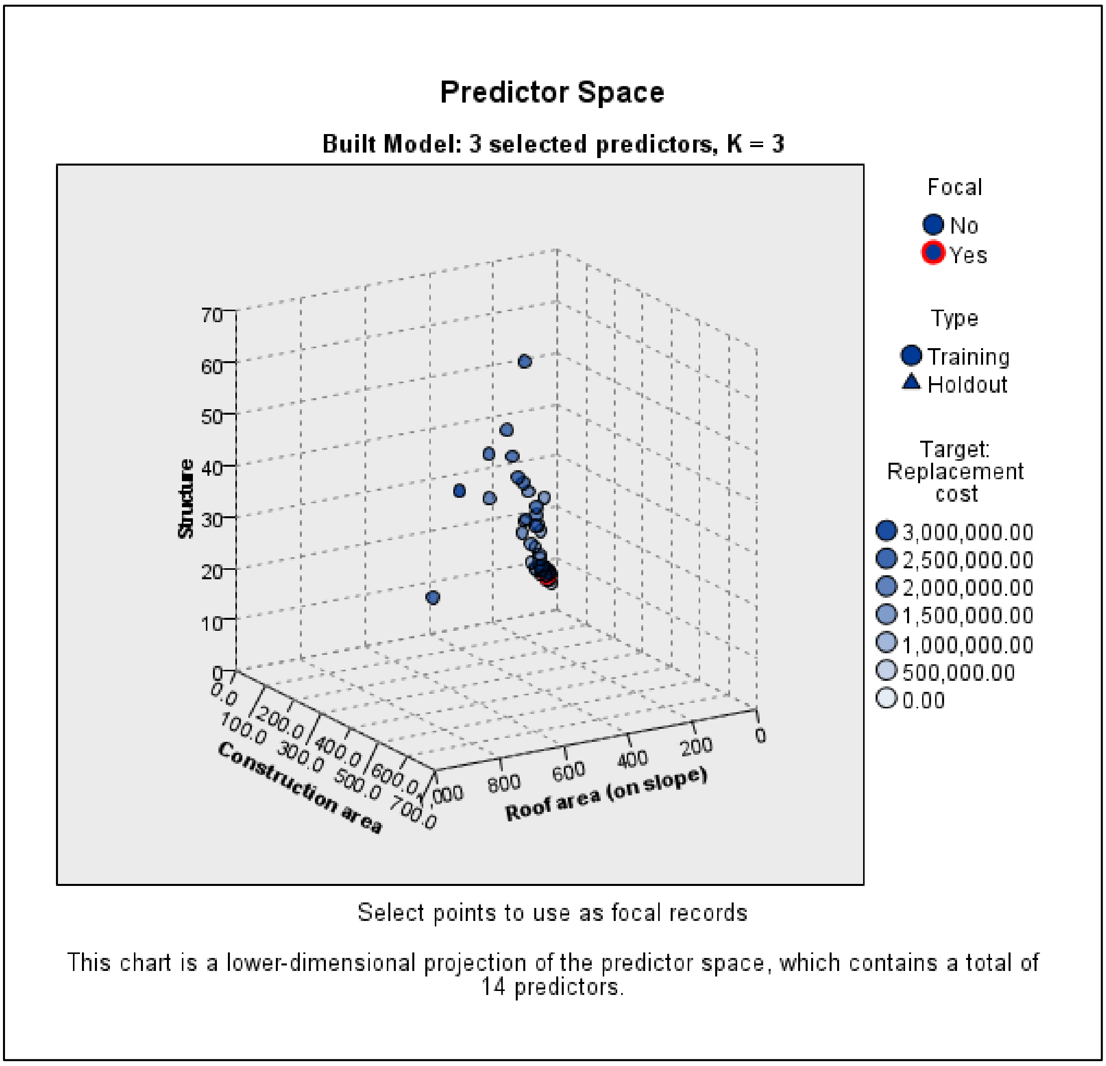

Figure 7.22: Predictor space for case 25 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.31: Nearest neighbours for case 25 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
25	27	28	26	0.334	0.370	0.396

7.2.5.1.26 Case 26

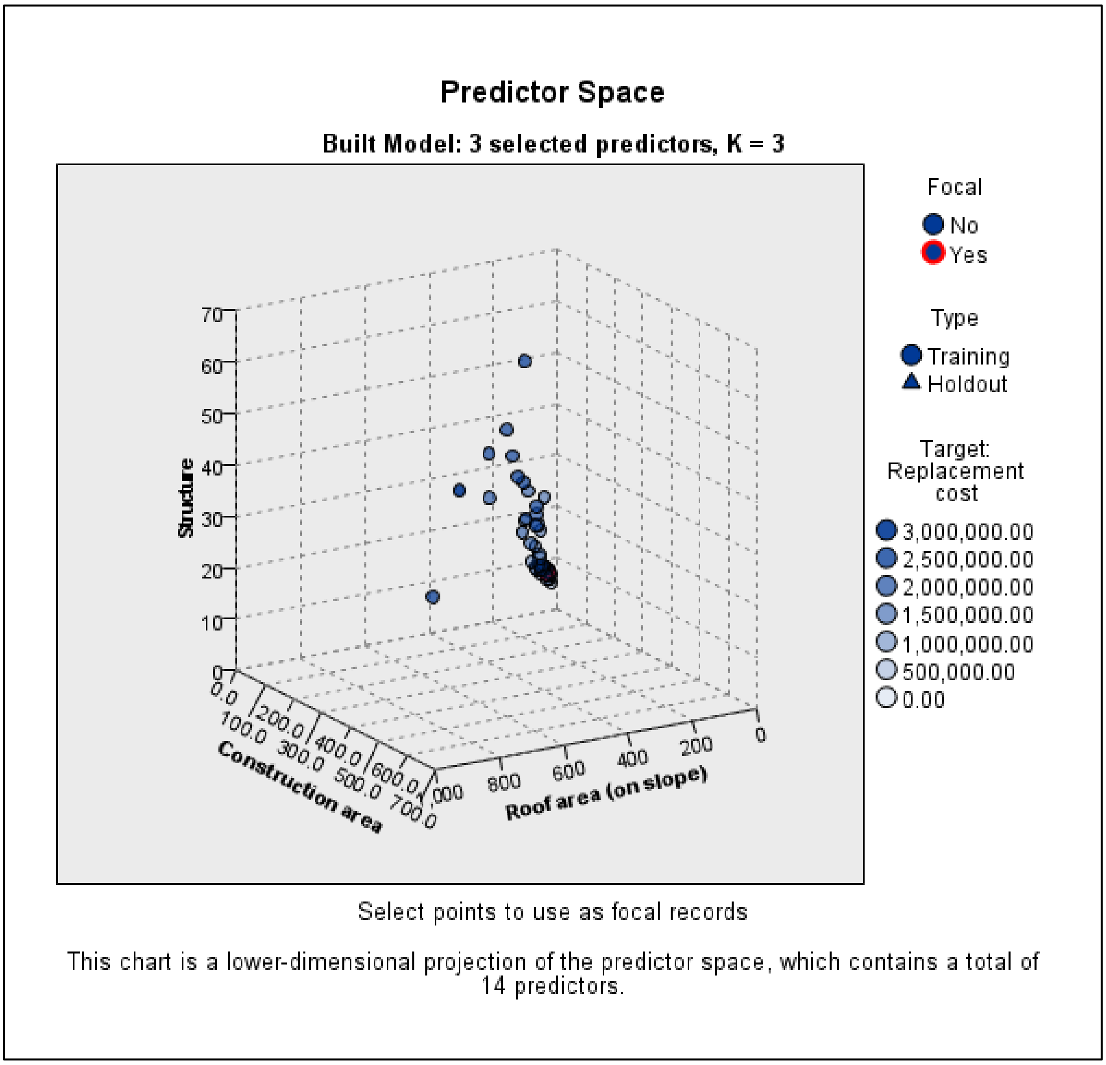

Figure 7.23: Predictor space for case 26 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.32: Nearest neighbours for case 26 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
26	27	28	25	0.268	0.332	0.396

7.2.5.1.27 Case 27

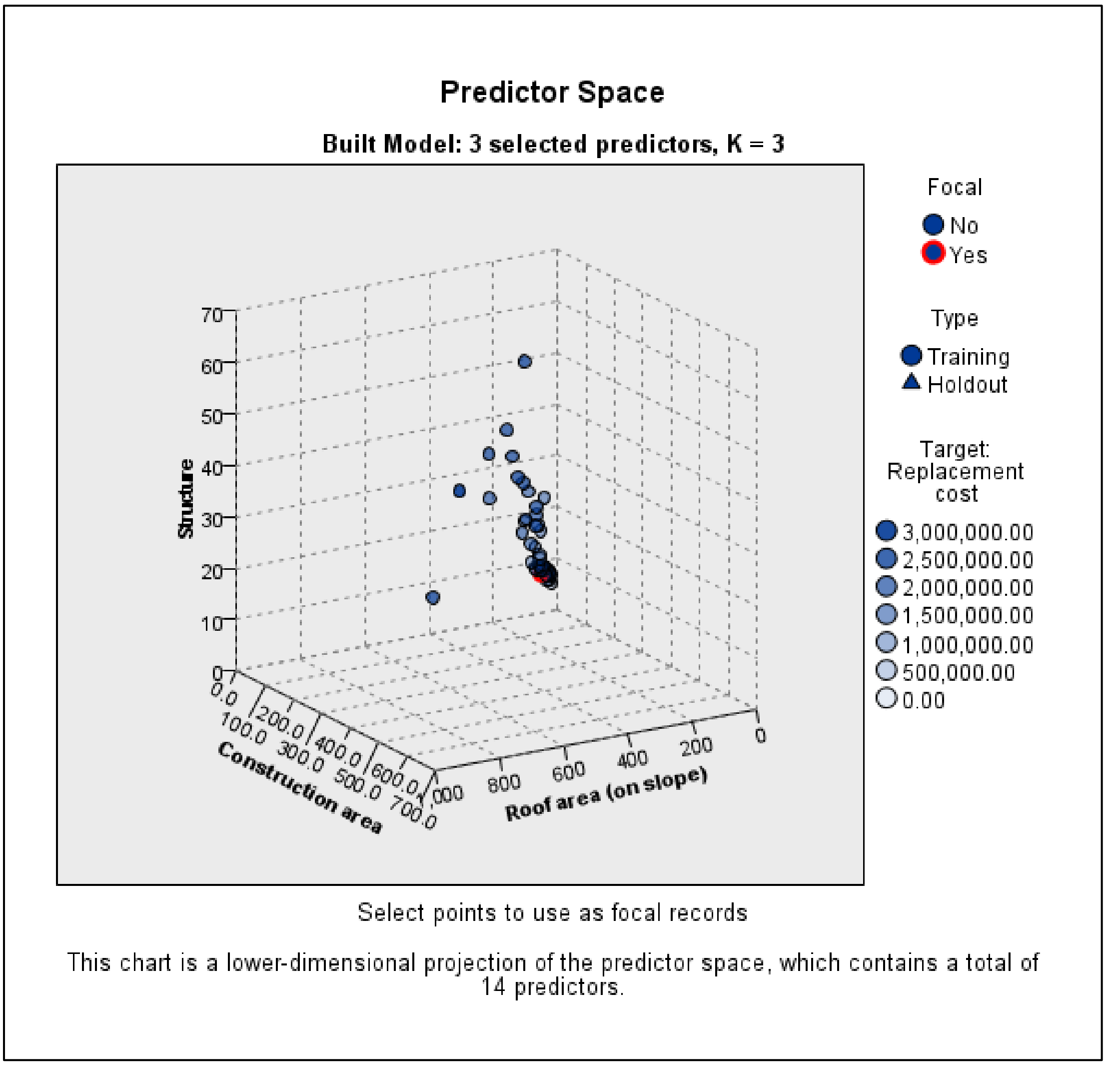

Figure 7.30: Predictor space for case 27 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.33: Nearest neighbours for case 27 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
27	28	31	29	0.113	0.223	0.250

7.2.5.1.28 Case 28

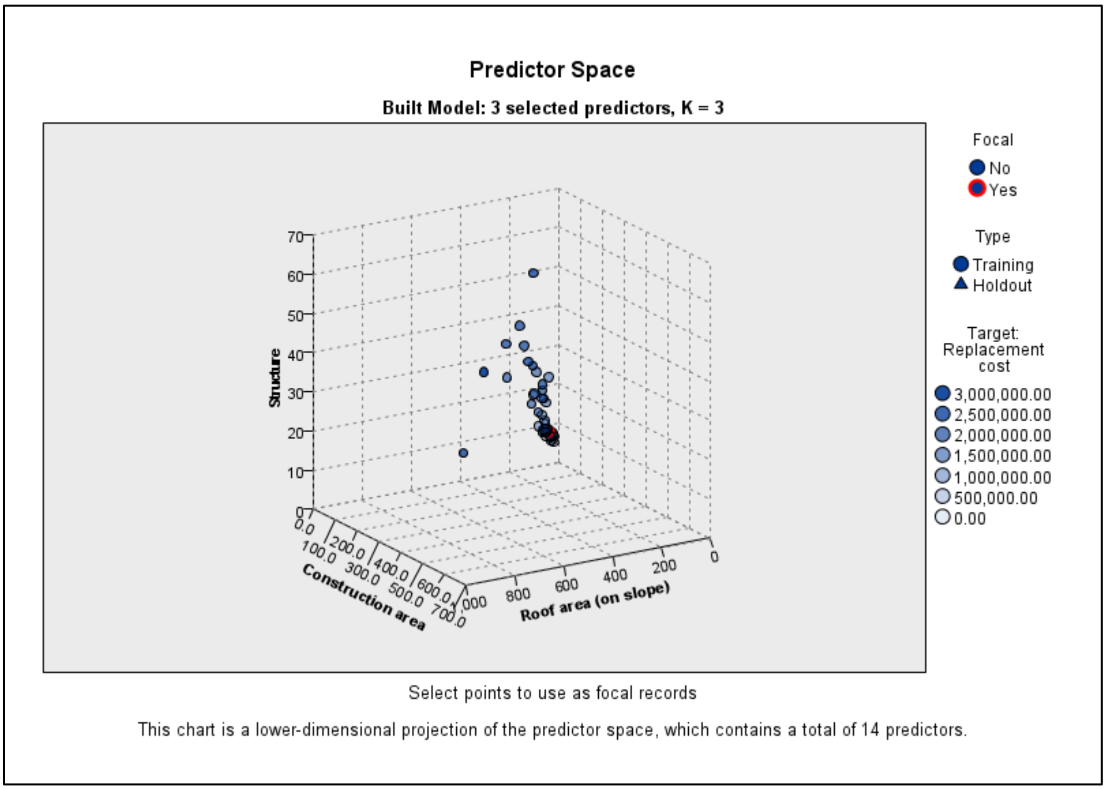

Figure 7.24: Predictor space for case 28 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.34: Nearest neighbours for case 28 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
28	27	31	29	0.113	0.159	0.245

7.2.5.1.29 Case 29

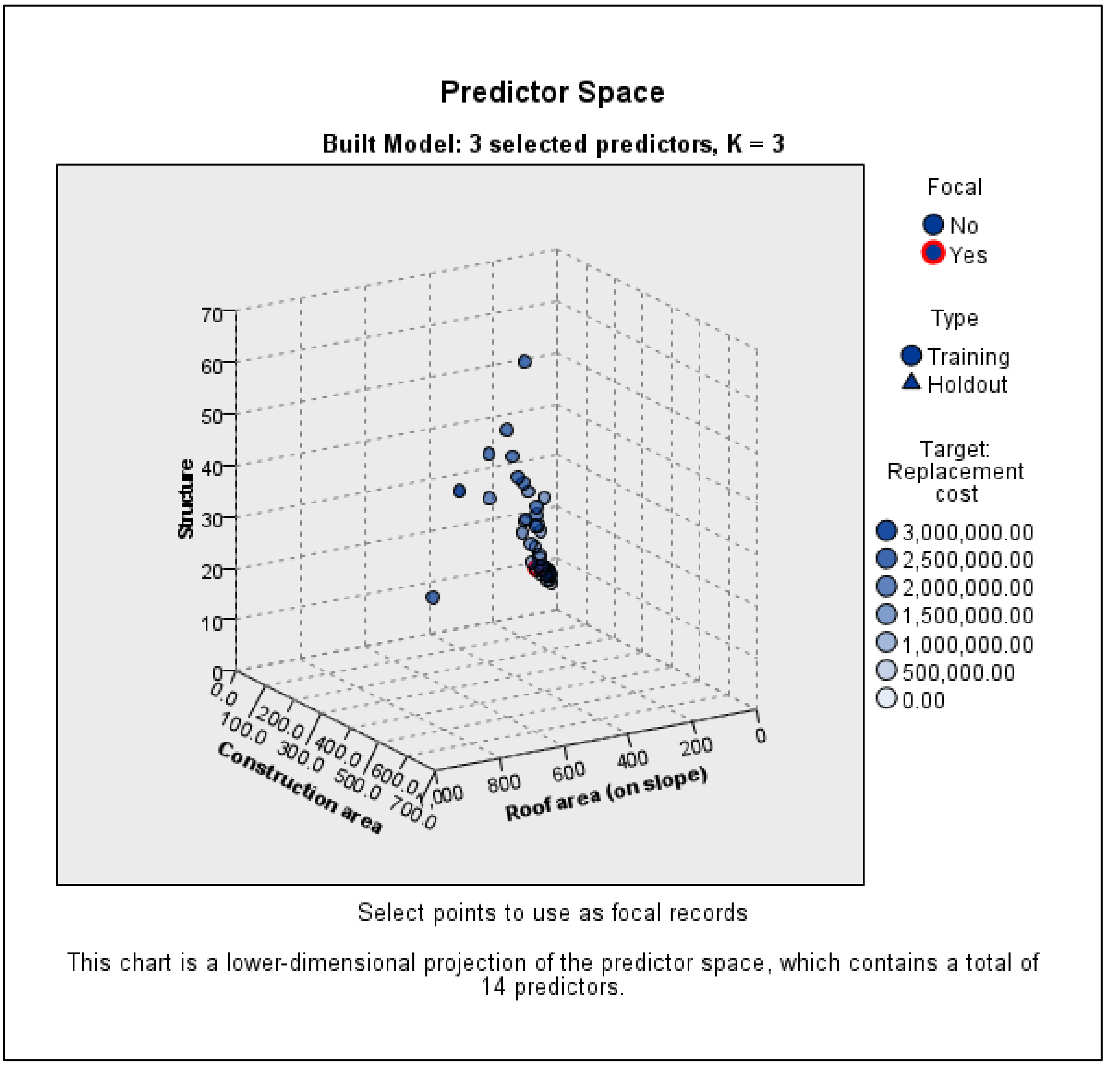

Figure 7.25: Predictor space for case 29 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.35: Nearest neighbours for case 29 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
29	30	31	28	0.186	0.237	0.245

7.2.5.1.30 Case 30

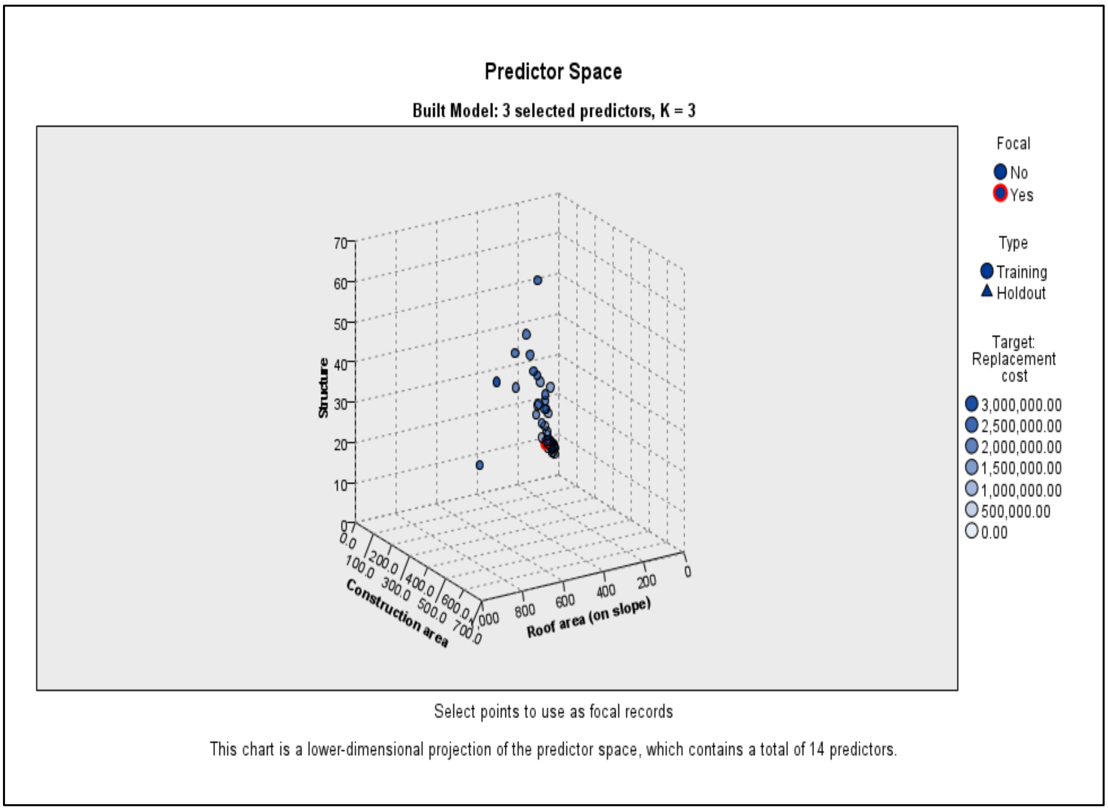

Figure 7.26: Predictor space for case 30 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.36: Nearest neighbours for case 30 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
30	29	31	28	0.186	0.249	0.286

7.2.5.1.31 Case 31

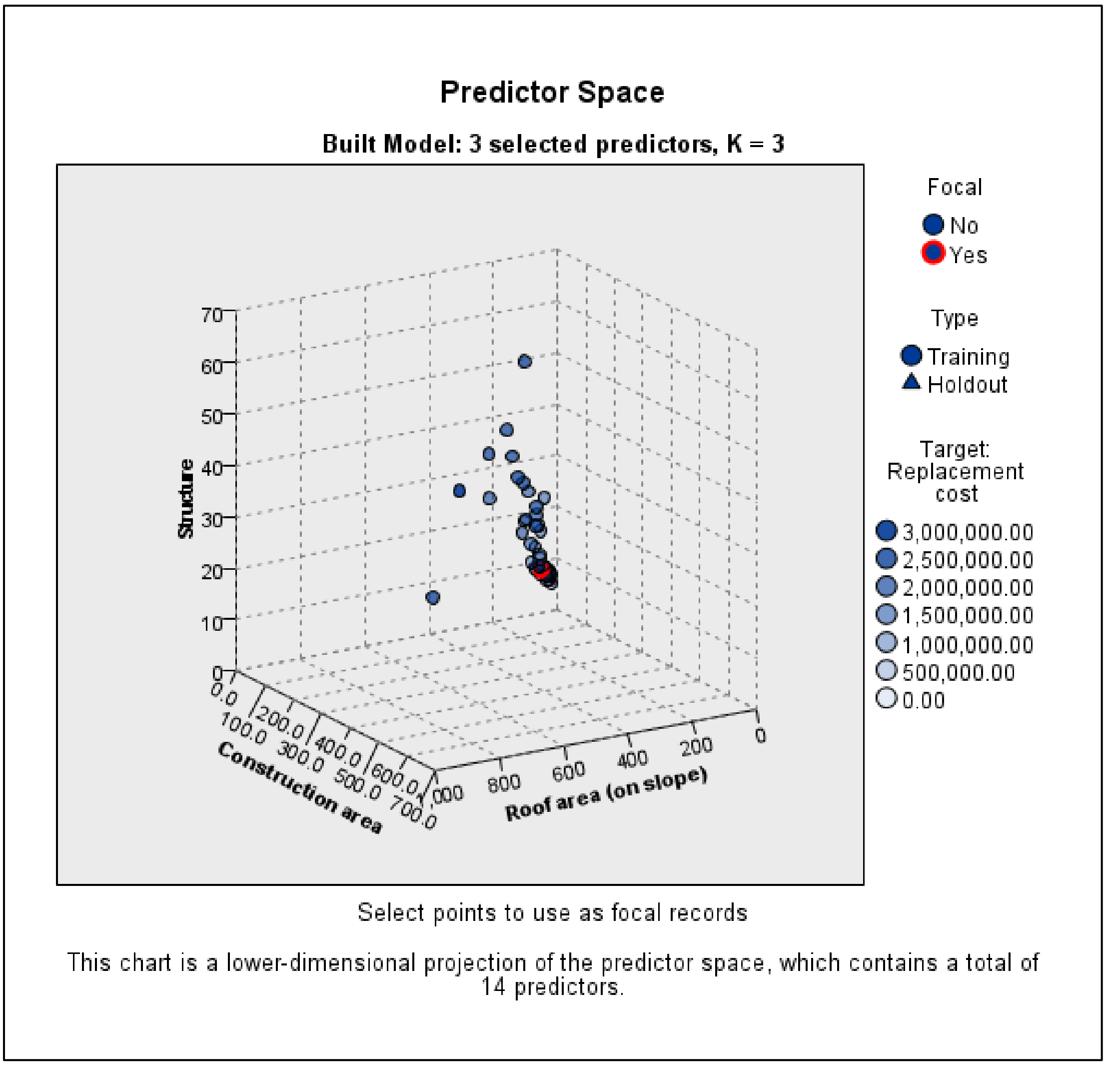

Figure 7.27: Predictor space for case 31 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.37: Nearest neighbours for case 31 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
31	28	27	29	0.159	0.223	0.237

7.2.5.1.32 Case 32

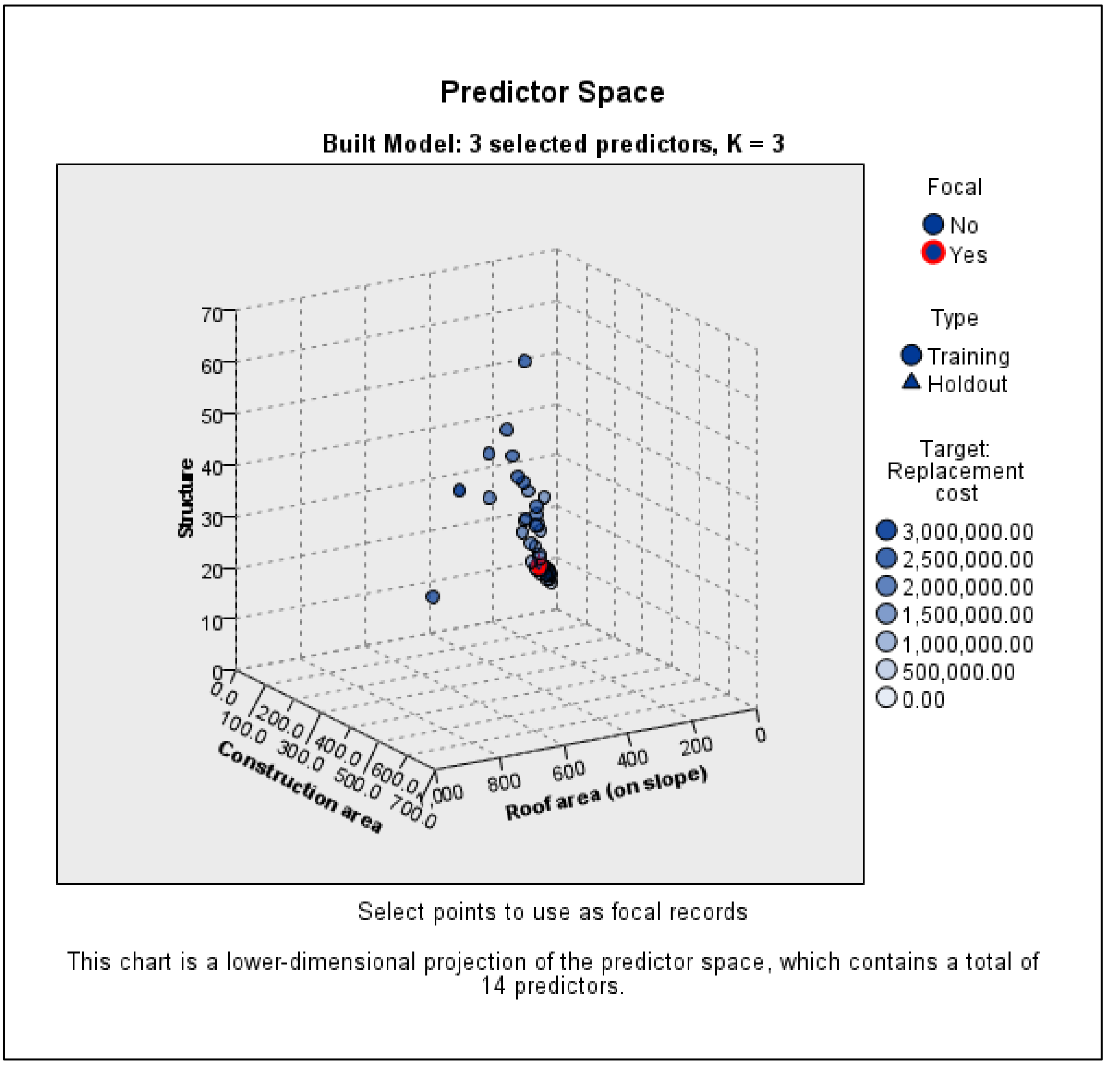

Figure 7.28: Predictor space for case 32 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.38: Nearest neighbours for case 32 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
32	31	30	42	0.716	0.744	0.745

7.2.5.1.33 Case 33

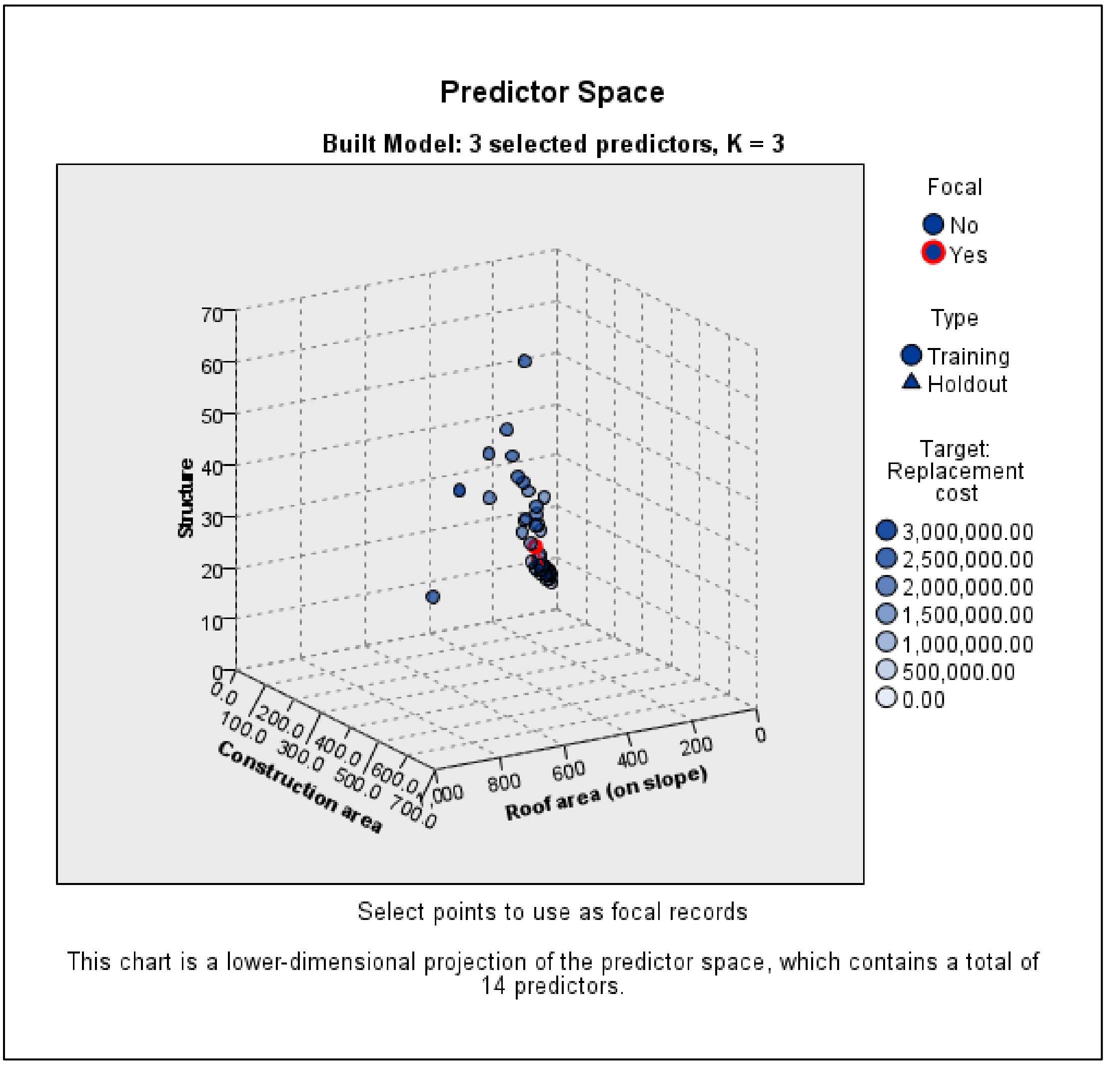

Figure 7.29: Predictor space for case 33 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.39: Nearest neighbours for case 33 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
33	18	17	35	1.227	1.512	1.842

7.2.5.1.34 Case 34

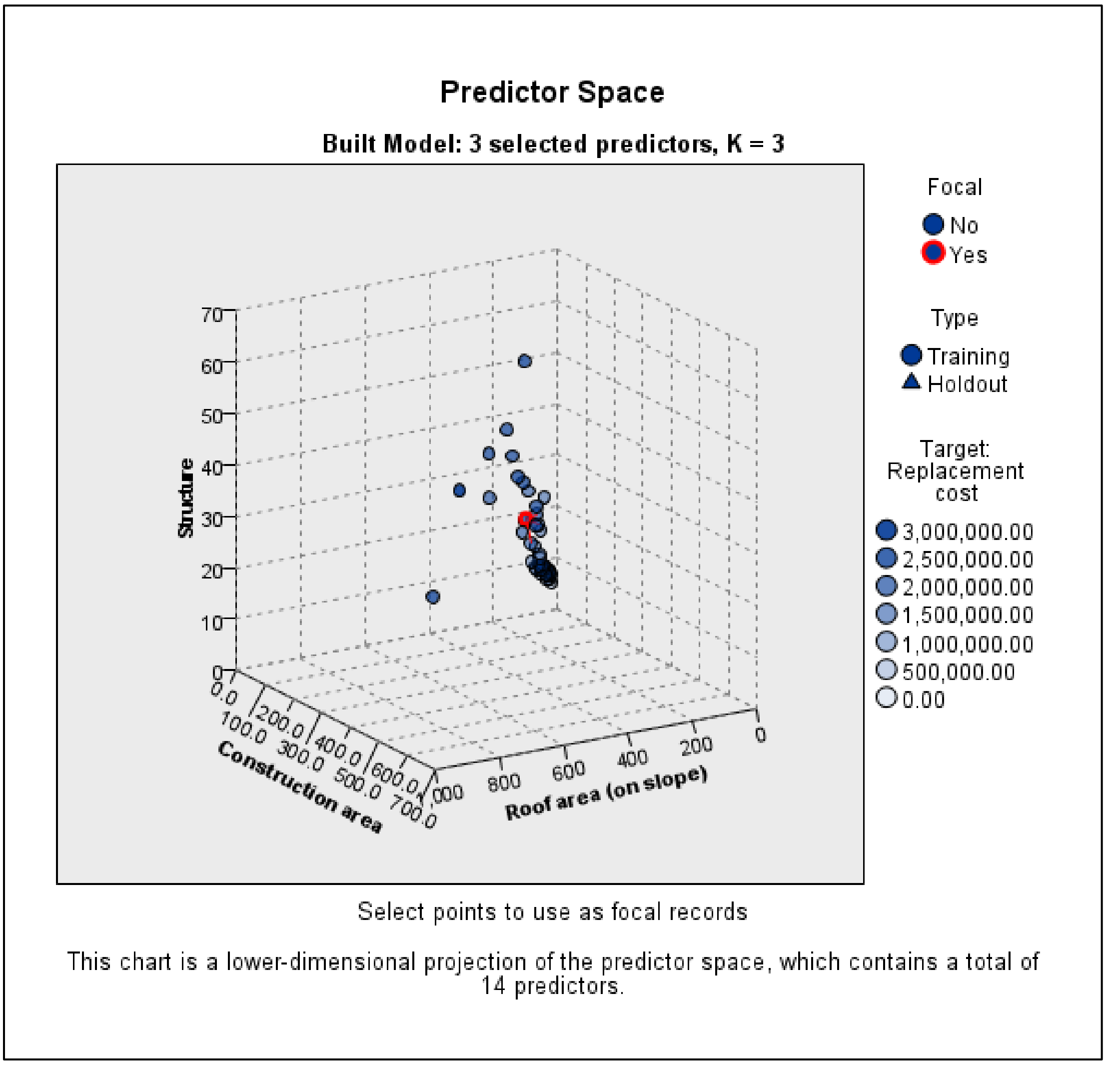

Figure 7.30: Predictor space for case 34 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.40: Nearest neighbours for case 34 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
34	7	21	39	0.894	1.170	1.221

7.2.5.1.35 Case 35

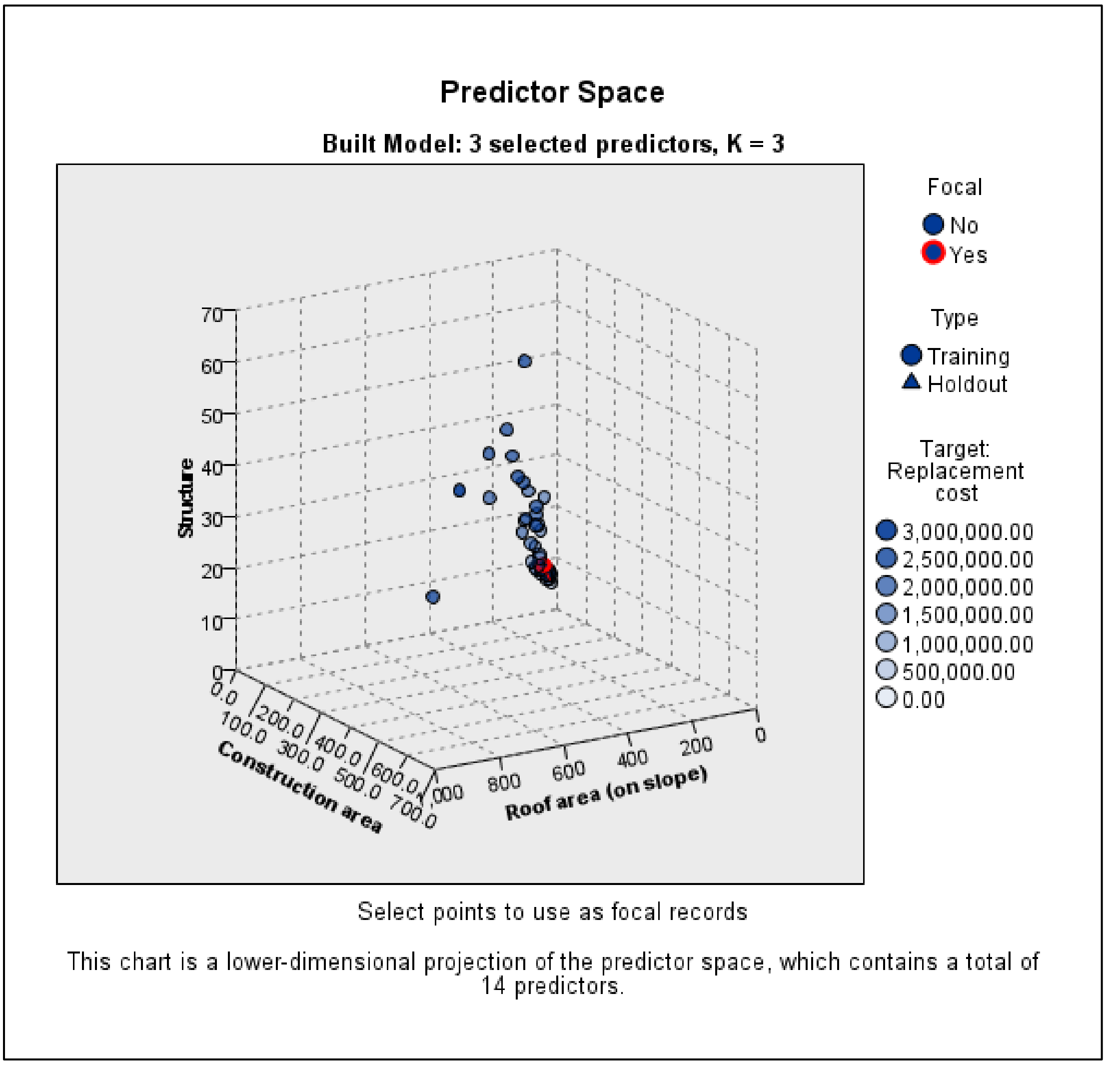

Figure 7.31: Predictor space for case 35 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.41: Nearest neighbours for case 35 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
35	36	31	24	0.379	0.584	0.607

7.2.5.1.36 Case 36

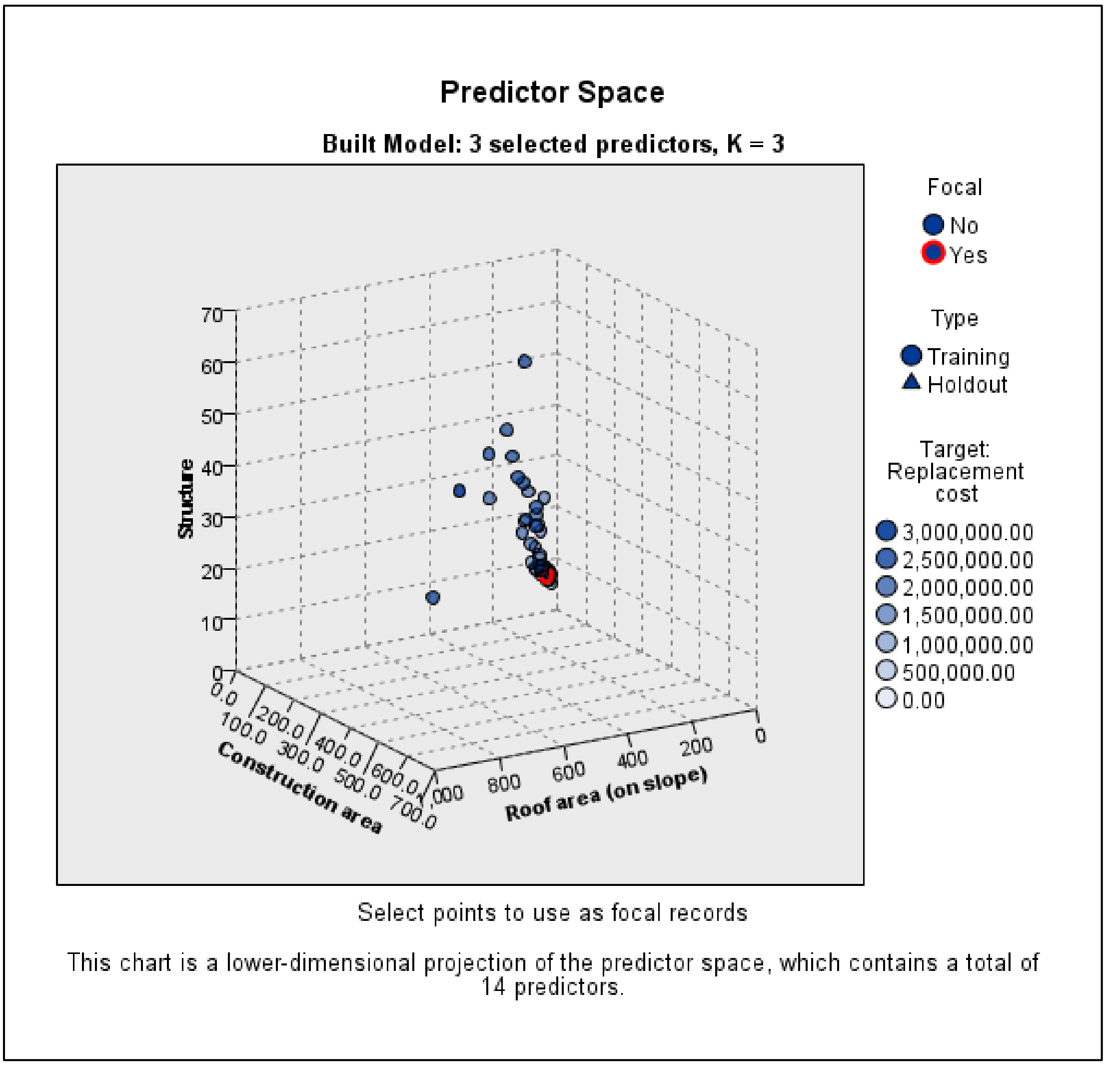

Figure 7.32: Predictor space for case 36 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 0.42: Nearest neighbours for case 36 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
36	35	24	23	0.379	0.391	0.450

7.2.5.1.37 Case 37

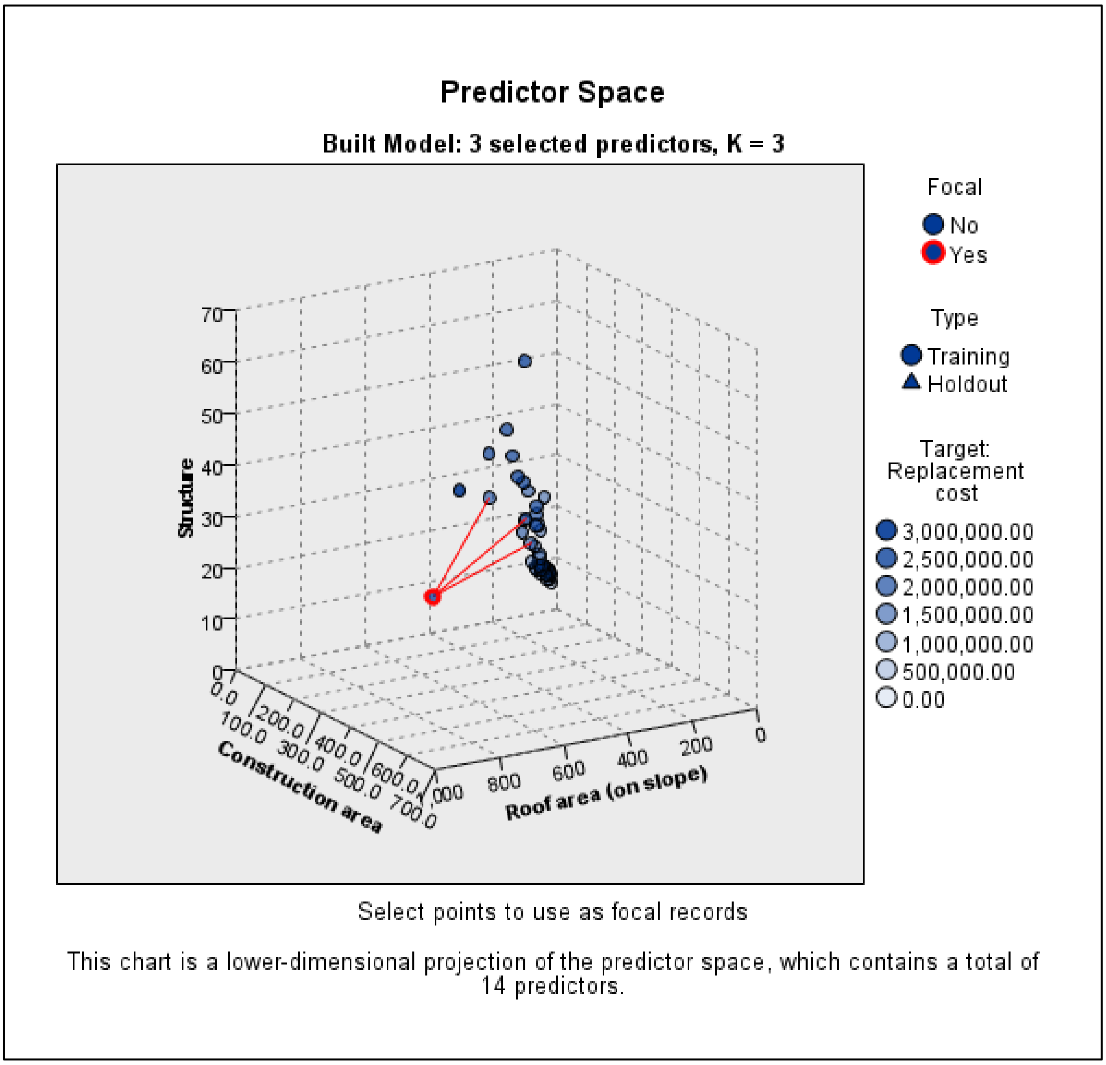

Figure 7.40: Predictor space for case 37 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.43: Nearest neighbours for case 37 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
37	20	34	7	1.692	1.763	1.832

7.2.5.1.38 Case 38

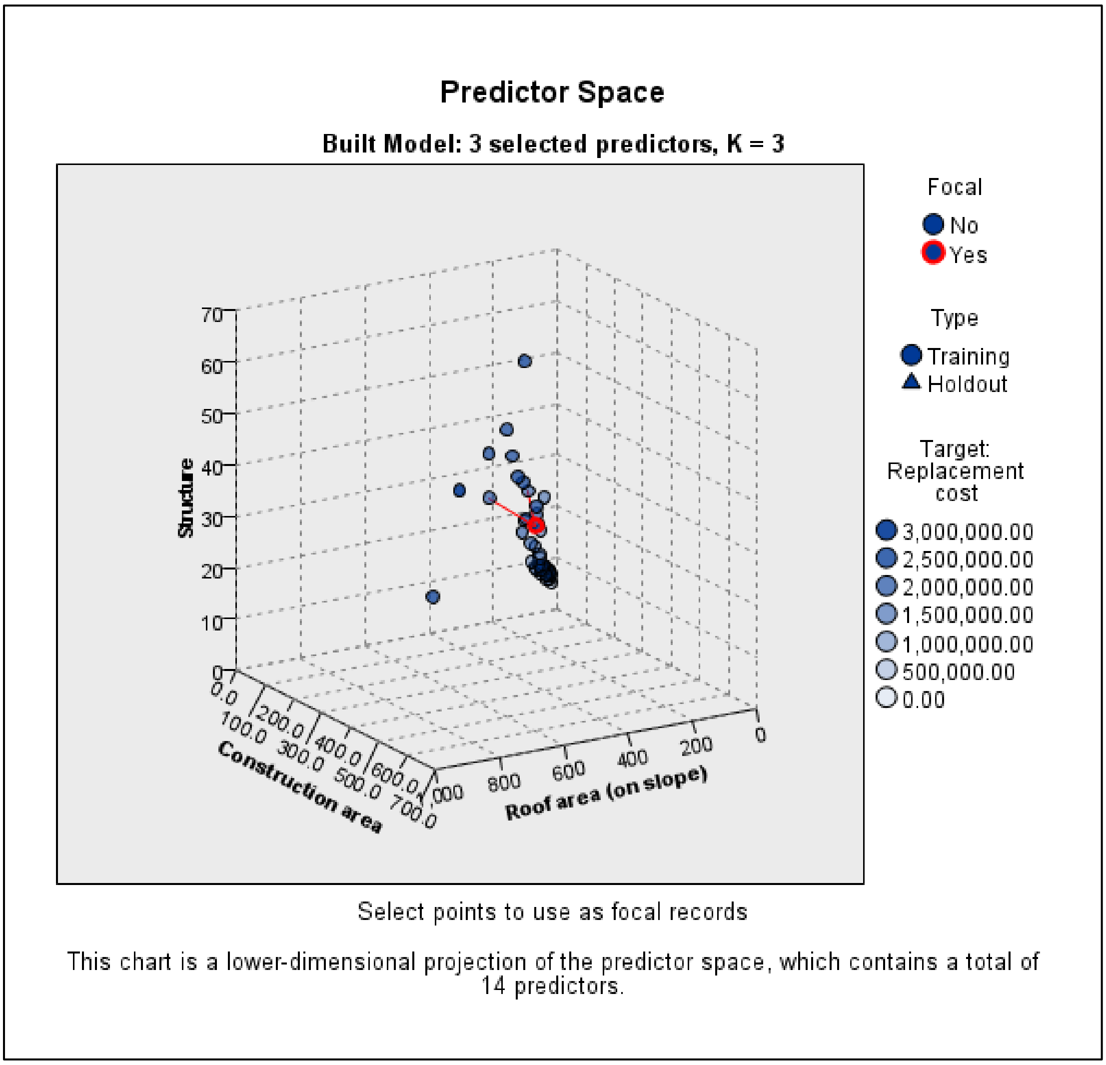

Figure 7.33: Predictor space for case 38 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.44: Nearest neighbours for case 38 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
38	9	10	20	1.098	1.159	1.271

7.2.5.1.39 Case 39

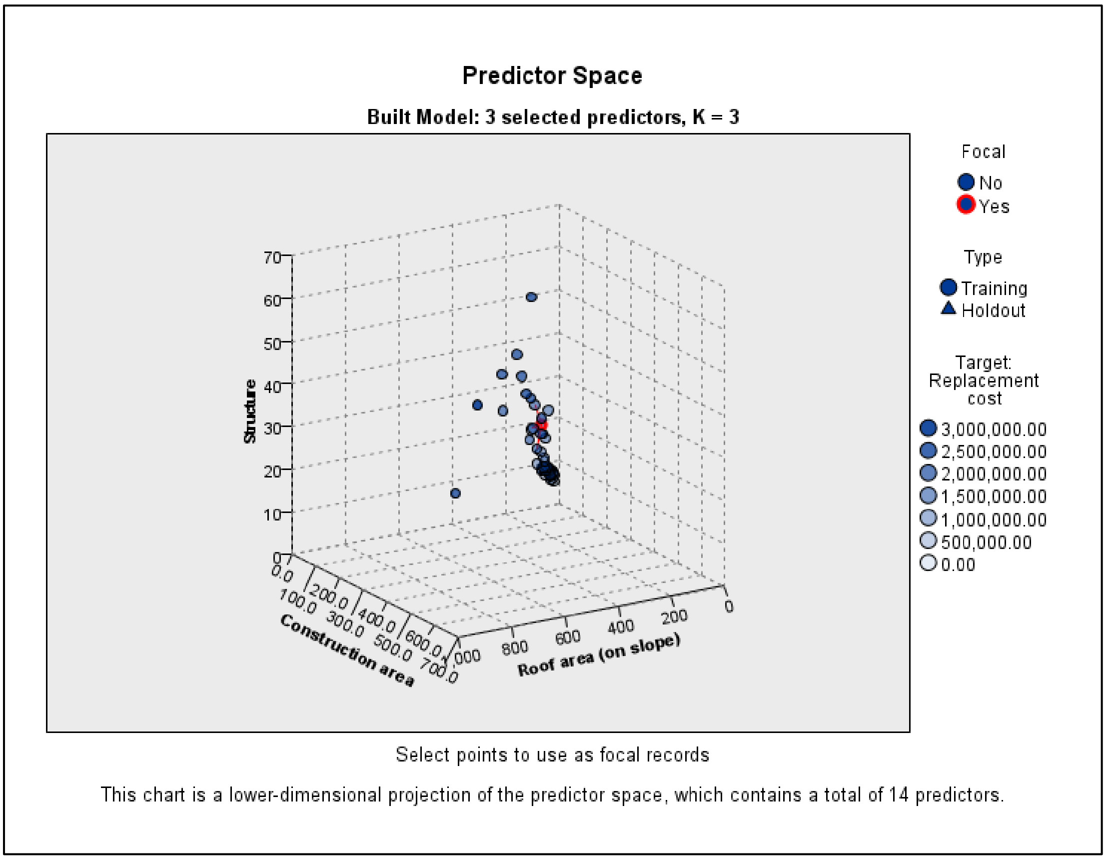

Figure 7.34: Predictor space for case 39 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.45: Nearest neighbours for case 39 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
39	34	10	7	1.221	1.285	1.326

7.2.5.1.40 Case 40

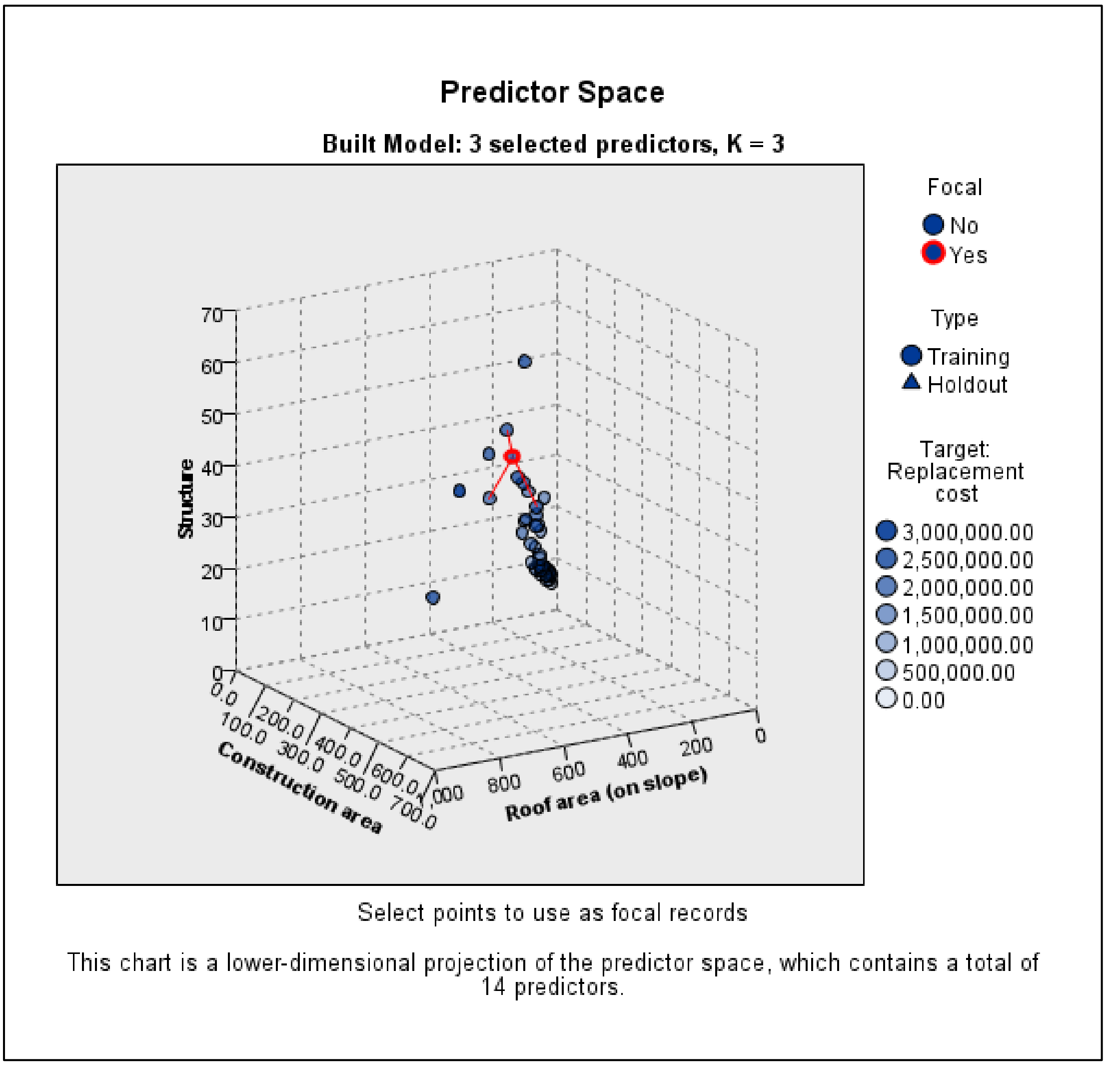

Figure 7.35: Predictor space for case 40 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.46: Nearest neighbours for case 40 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
40	19	20	13	2.775	2.828	2.889

7.2.5.1.41 Case 41

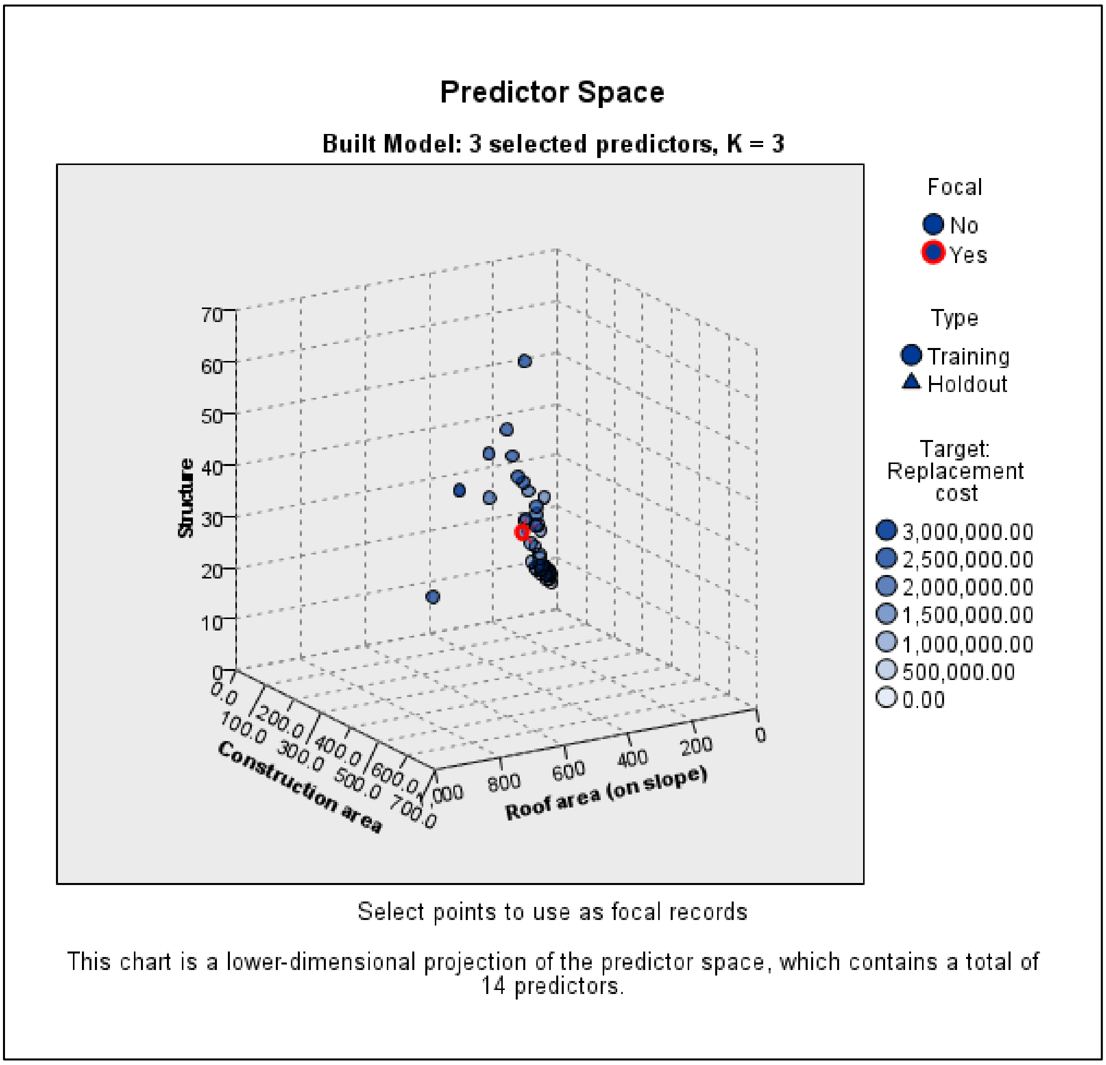

Figure 7.36: Predictor space for case 41 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.47: Nearest neighbours for case 41 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
41	34	21	7	1.310	1.557	1.588

7.2.5.1.42 Case 42

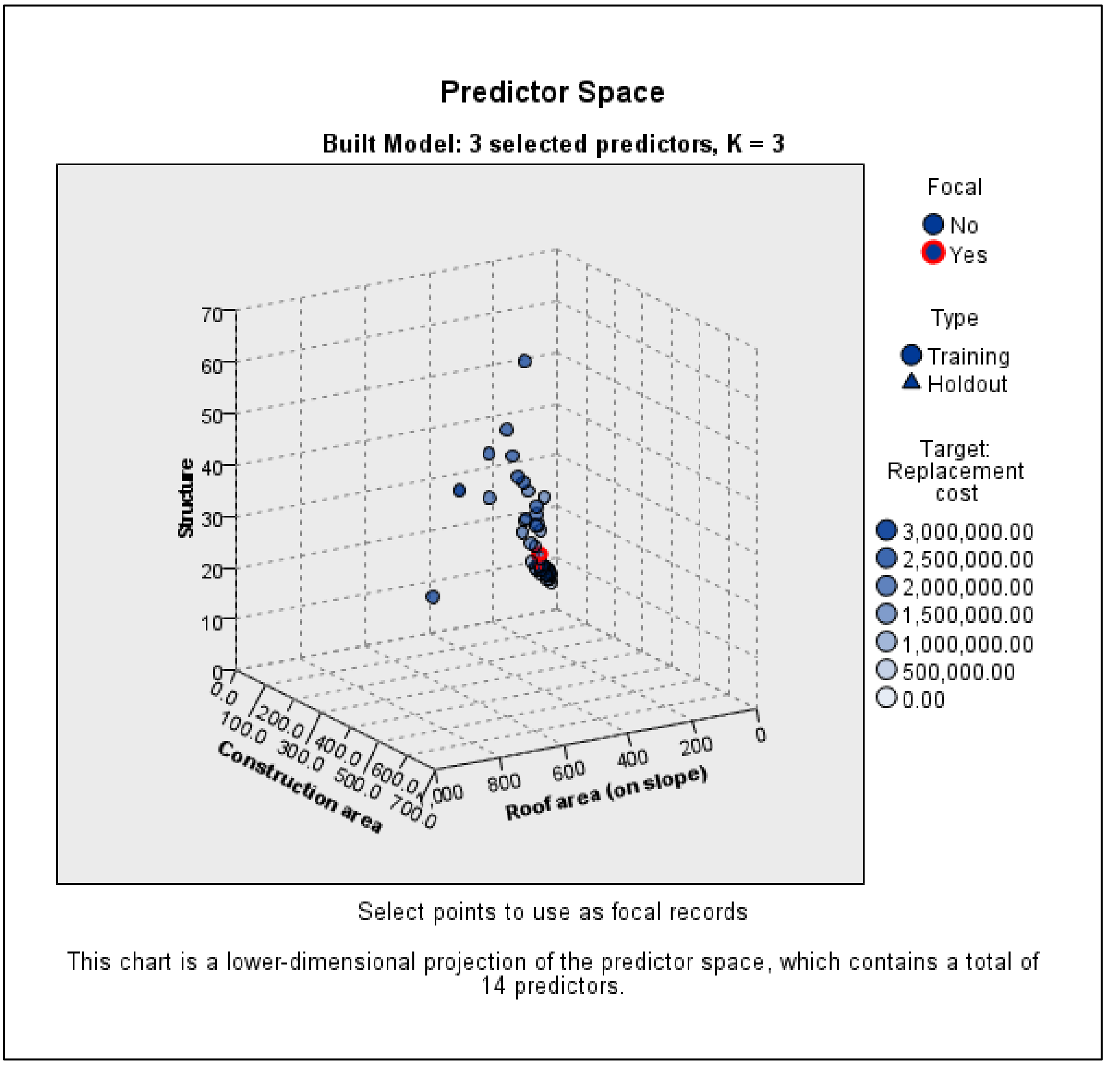

Figure 7.37: Predictor space for case 42 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.48: Nearest neighbours for case 42 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
42	30	31	29	0.581	0.629	0.660

7.2.5.1.43 Case 43

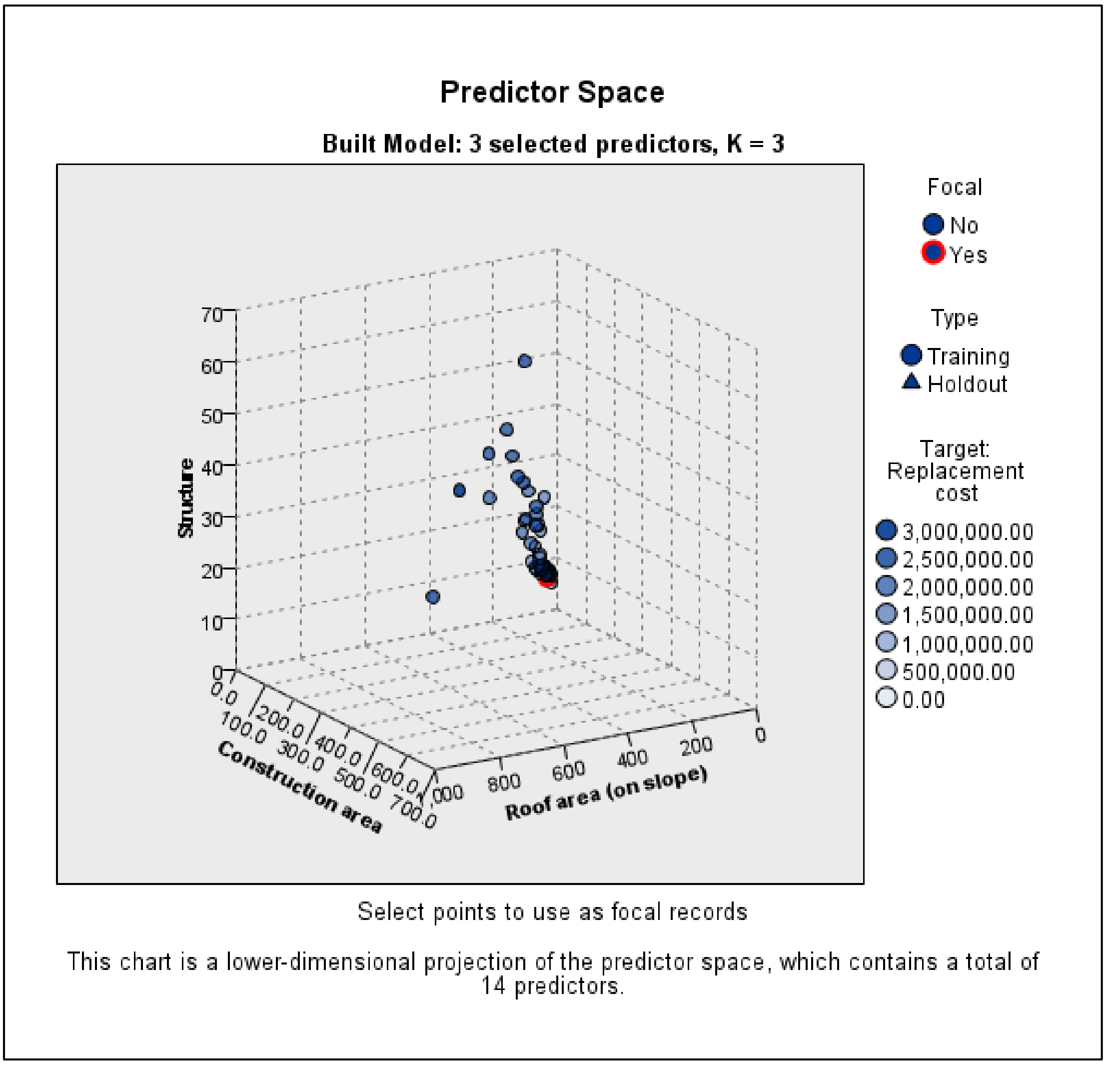

Figure 7.38: Predictor space for case 43 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.49: Nearest neighbours for case 43 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
43	23	24	44	0.343	0.358	0.450

7.2.5.1.44 Case 44

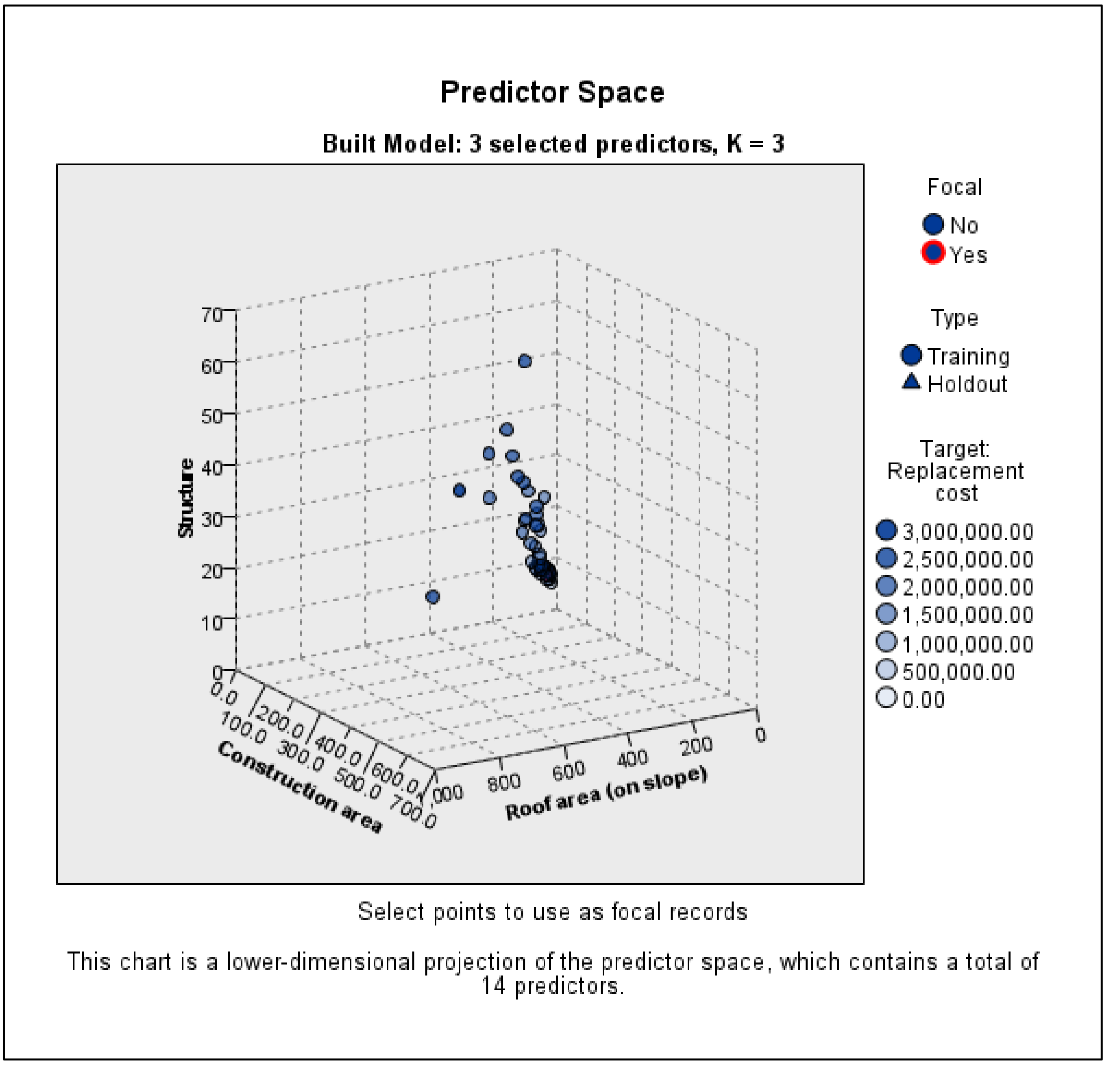

Figure 7.39: Predictor space for case 44 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.50: Nearest neighbours for case 44 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
44	43	24	23	0.450	0.496	0.507

7.2.5.1.45 Case 45

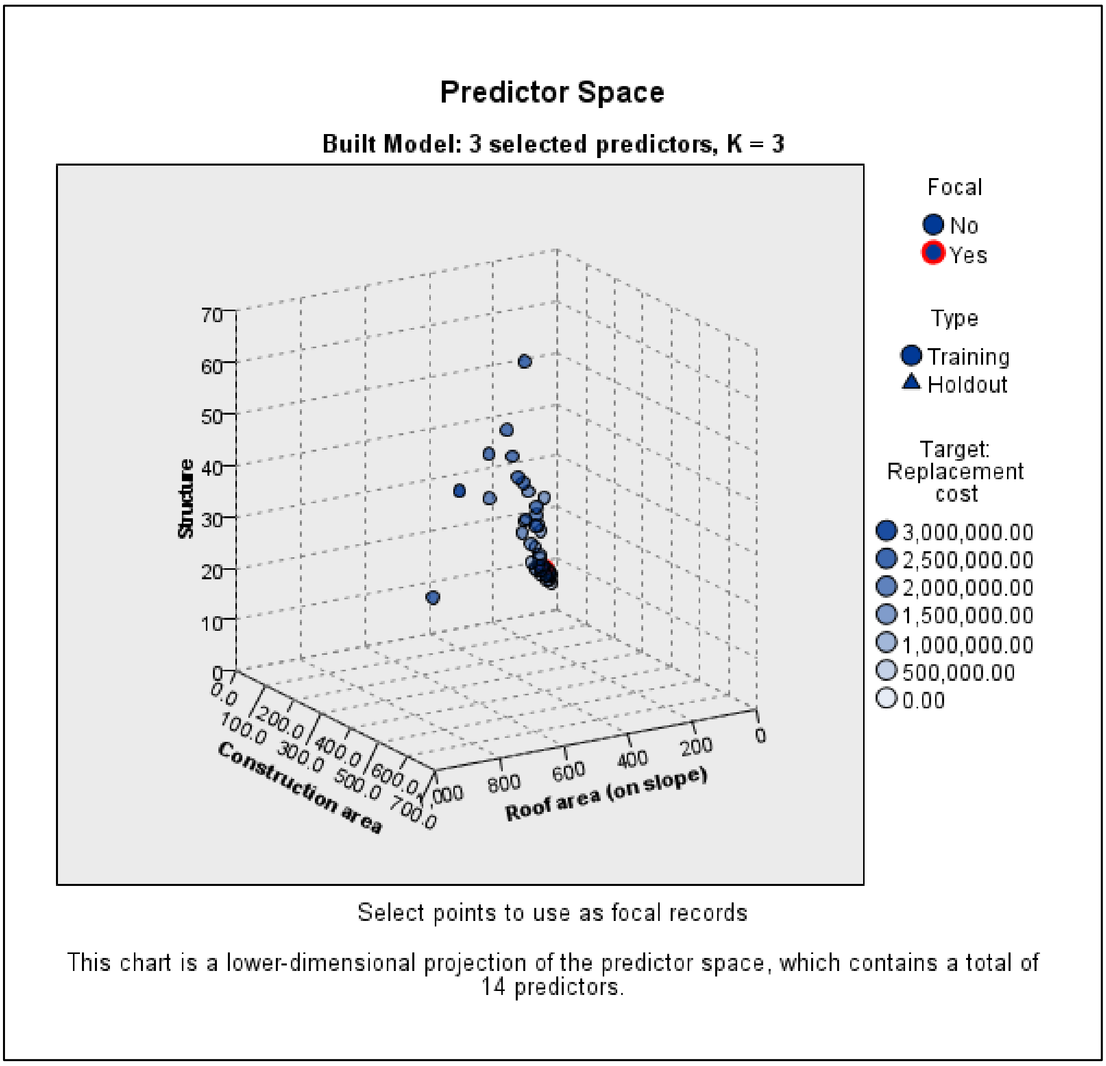

Figure 7.40: Predictor space for case 45 14-feature unweighted (generated by IBM® SPSS® Statistics)

Table 7.51: Nearest neighbours for case 45 14-feature unweighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
45	29	27	28	0.383	0.397	0.433

7.2.5.2 Nearest Neighbours for all the cases based on the 14-feature weighted scenario

7.2.5.2.1 Case 1

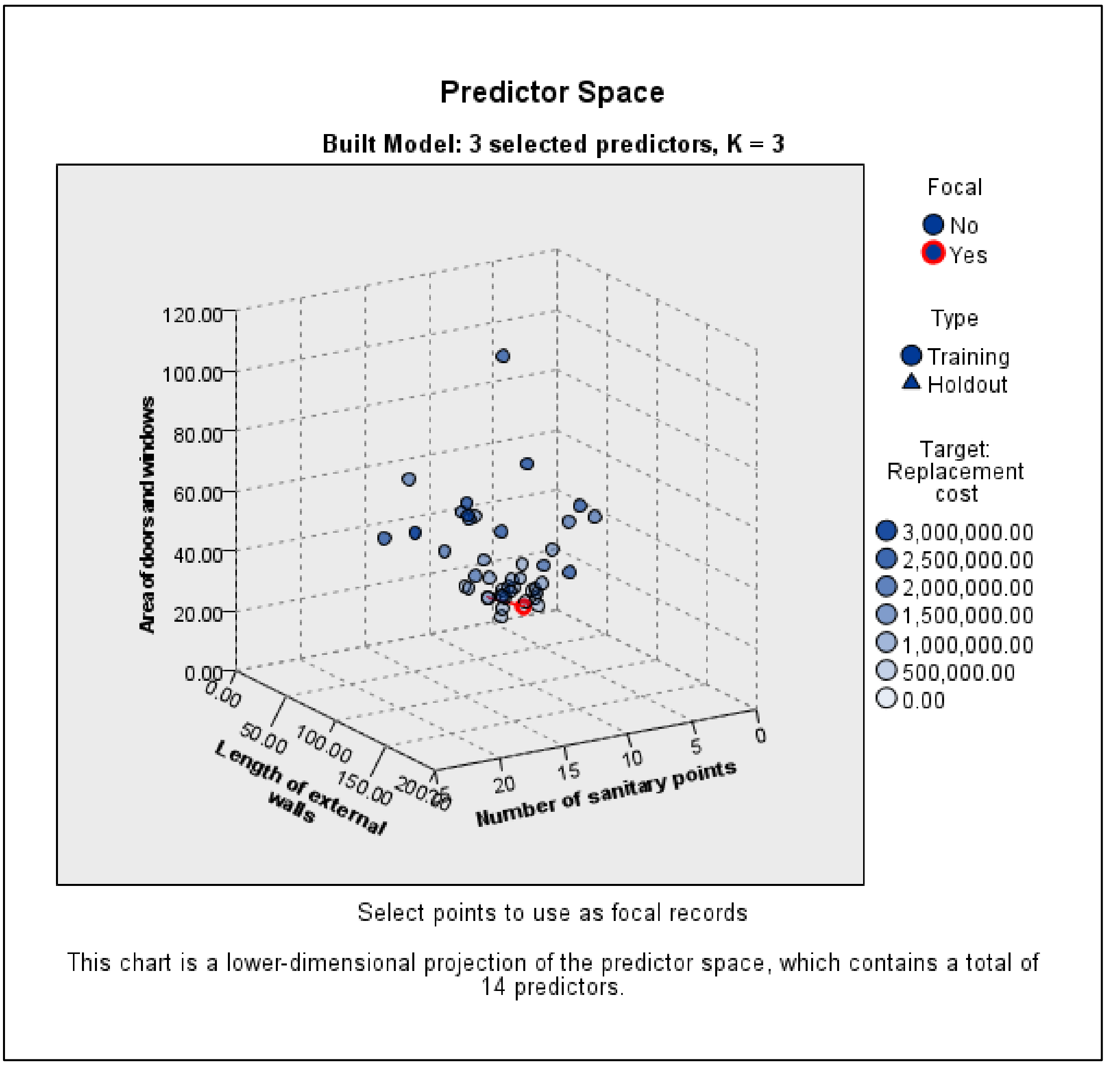

Figure 7.41: Predictor space for case 1 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 0.52: Nearest neighbours for case 1 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
1	2	3	4	0.081	0.123	0.156

7.2.5.2.2 Case 2

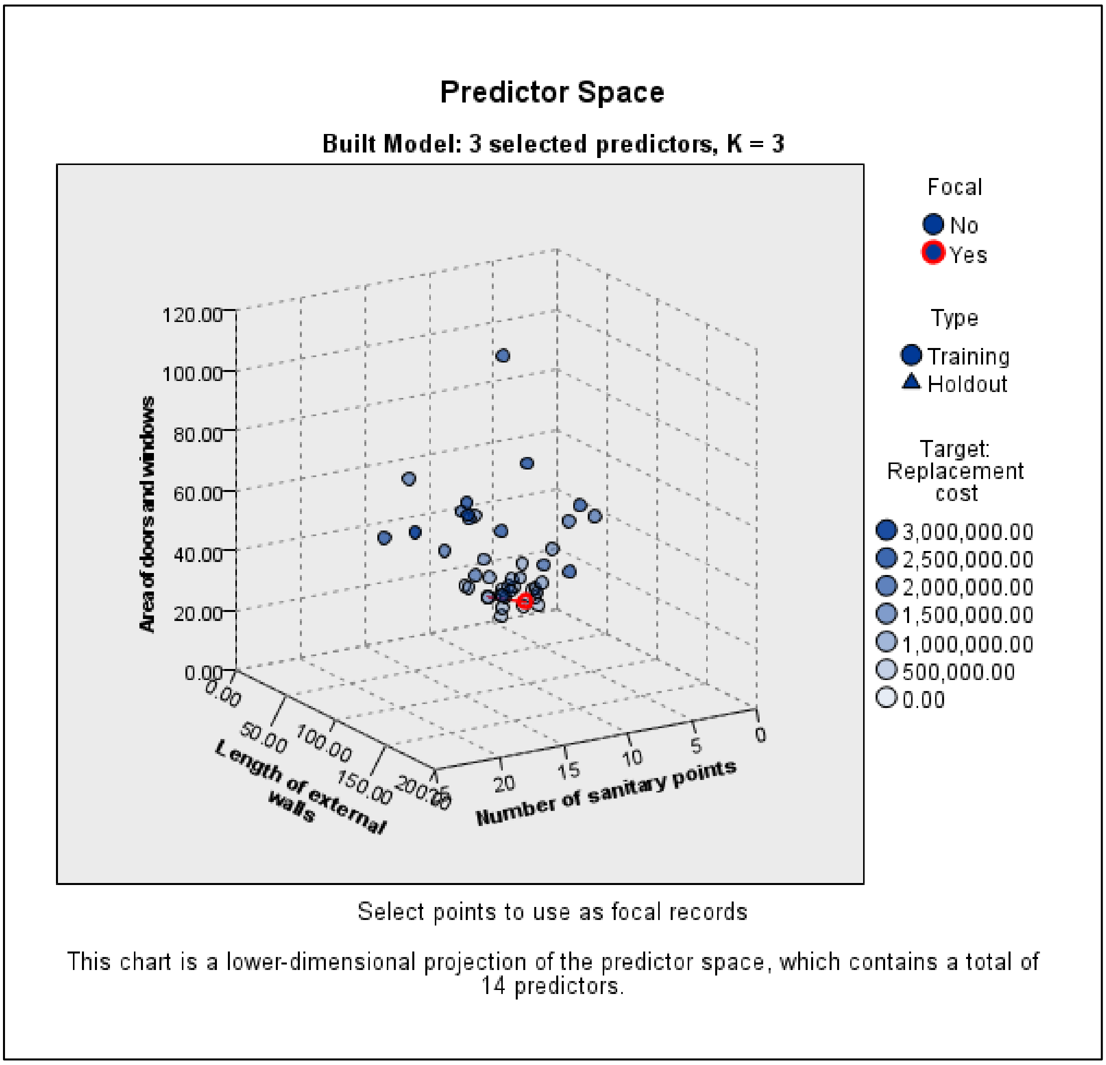

Figure 7.50: Predictor space for case 2 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.53: Nearest neighbours for case 2 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
2	1	3	4	0.081	0.090	0.106

7.2.5.2.3 Case 3

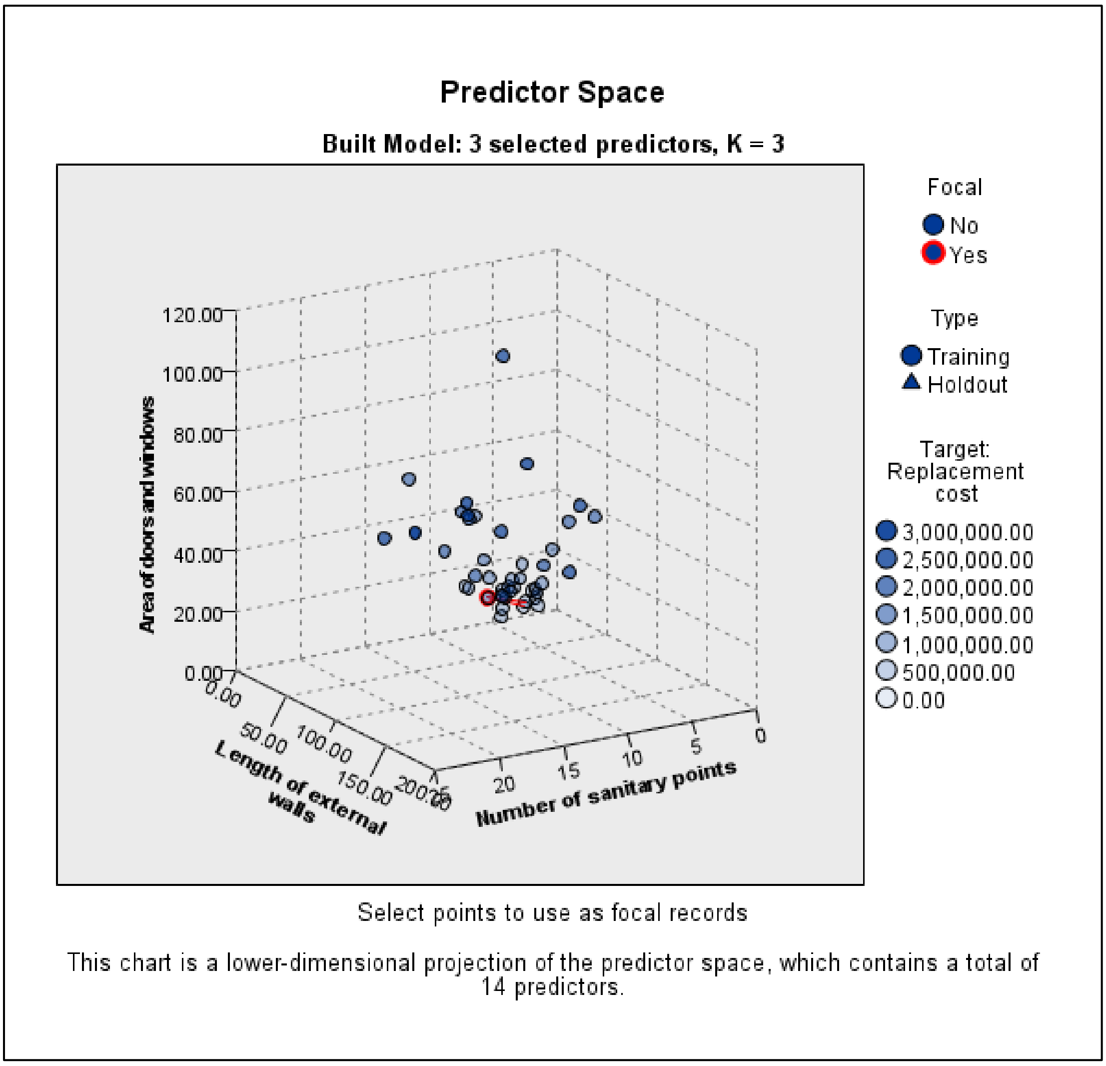

Figure 7.42: Predictor space for case 3 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.54: Nearest neighbours for case 3 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbors			Nearest Distances		
	1	2	3	1	2	3
3	4	2	1	0.055	0.090	0.123

7.2.5.2.4 Case 4

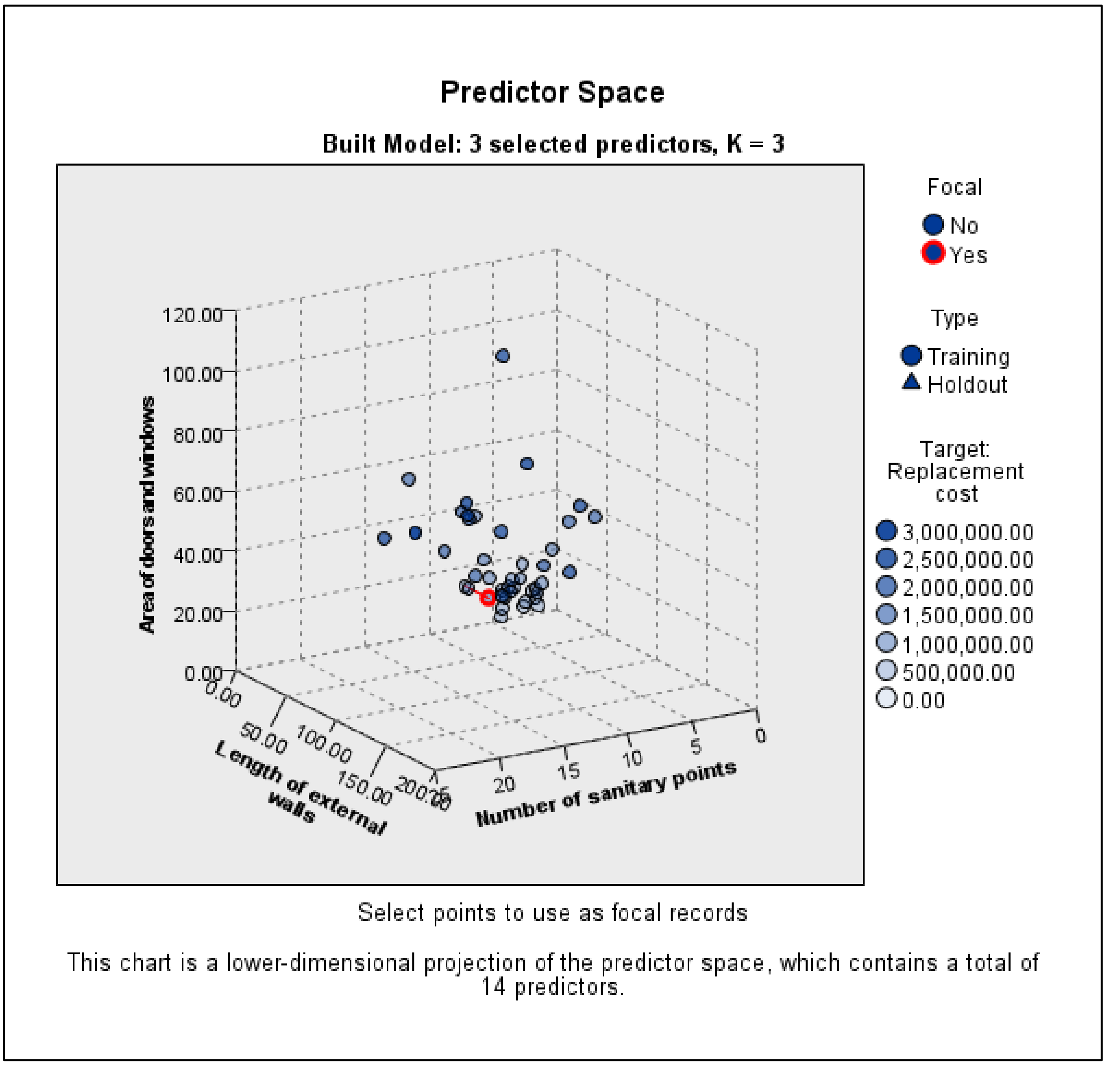

Figure 7.43: Predictor space for case 4 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.55: Nearest neighbours for case 4 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
4	3	5	6	0.055	0.090	0.097

7.2.5.2.5 Case 5

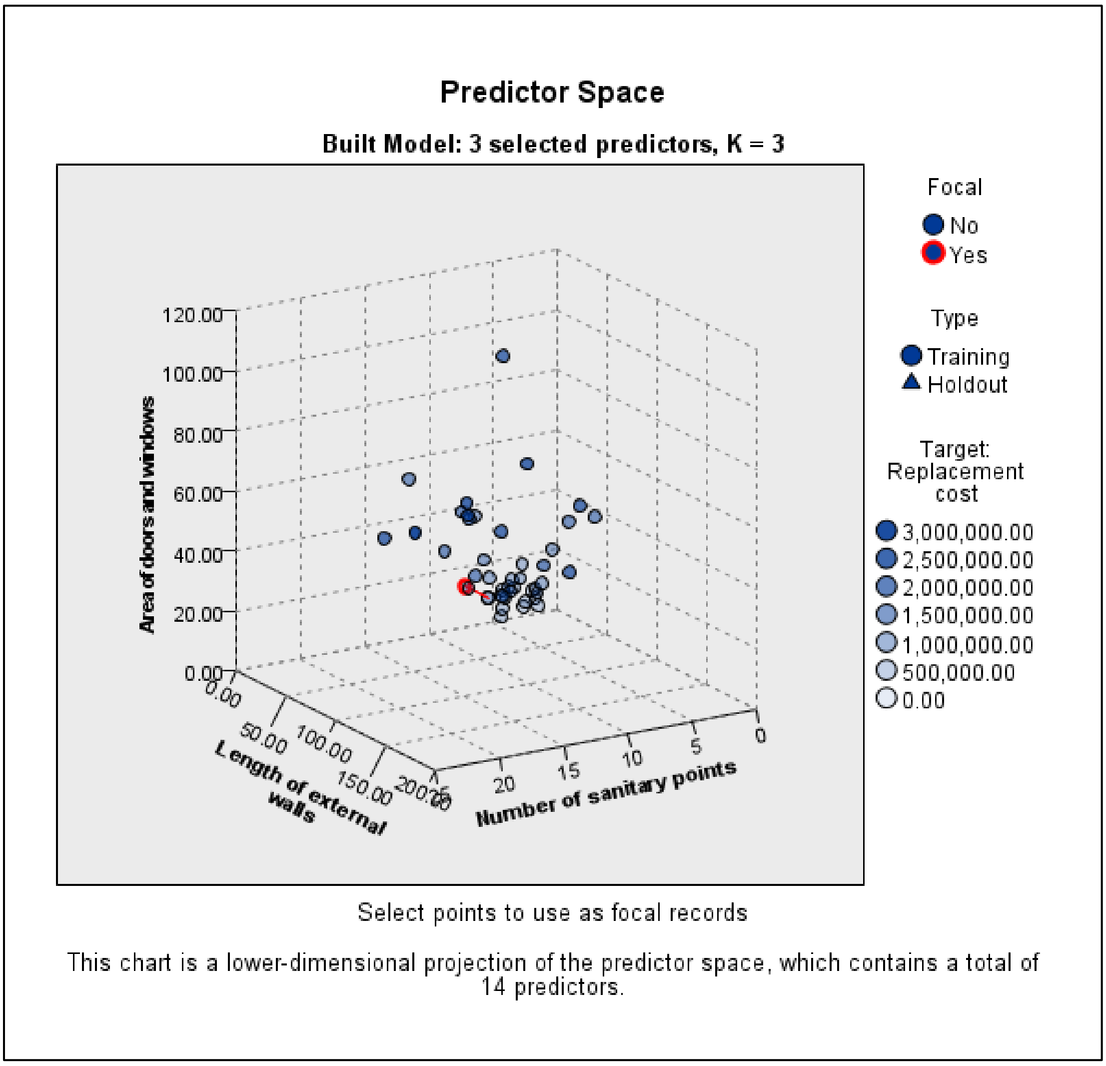

Figure 7.44: Predictor space for case 5 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.56: Nearest neighbours for case 5 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
5	6	4	3	0.029	0.090	0.131

7.2.5.2.6 Case 6

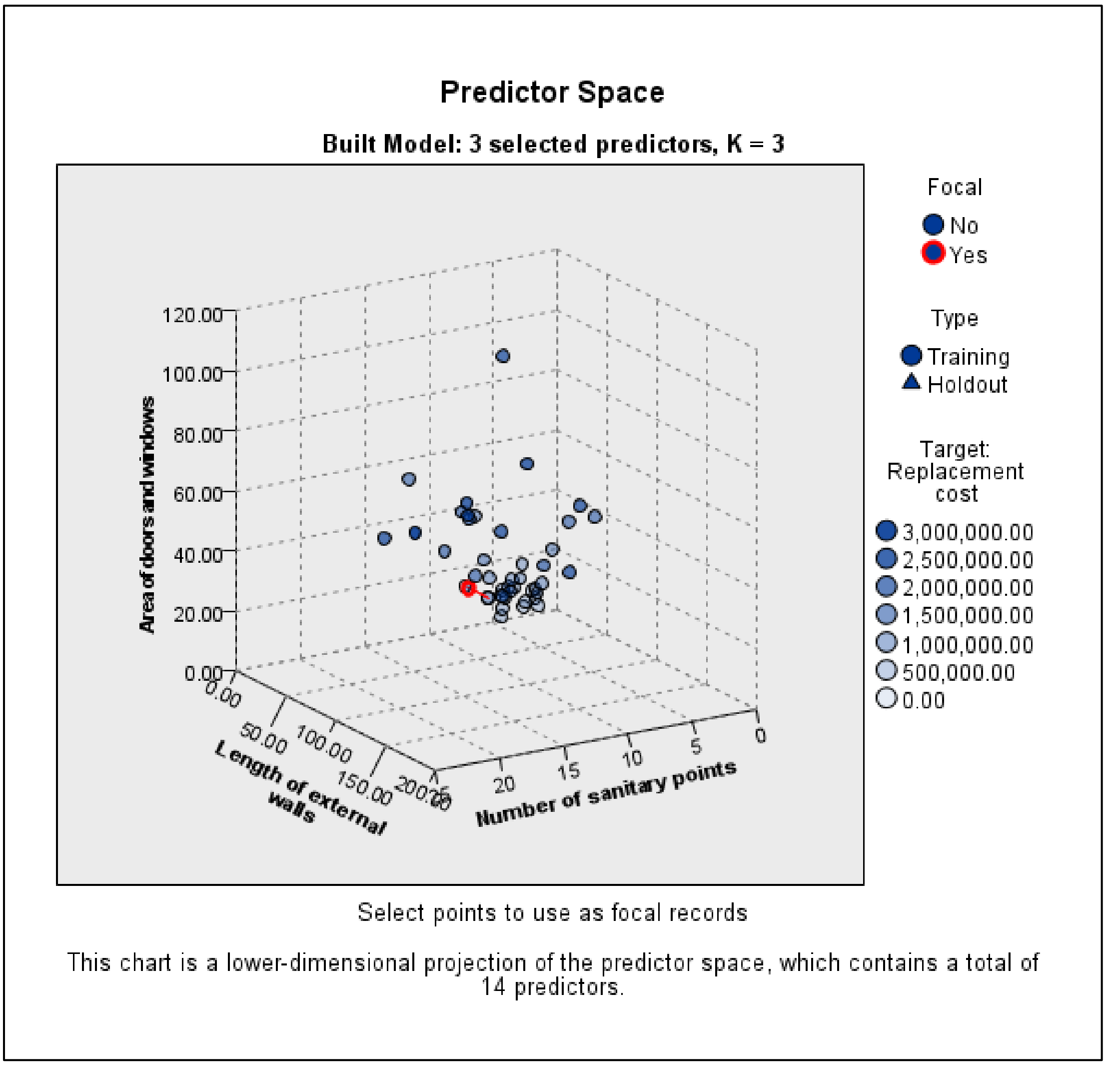

Figure 7.45: Predictor space for case 6 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.57: Nearest neighbours for case 6 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
6	5	4	3	0.029	0.097	0.137

7.2.5.2.7 Case 7

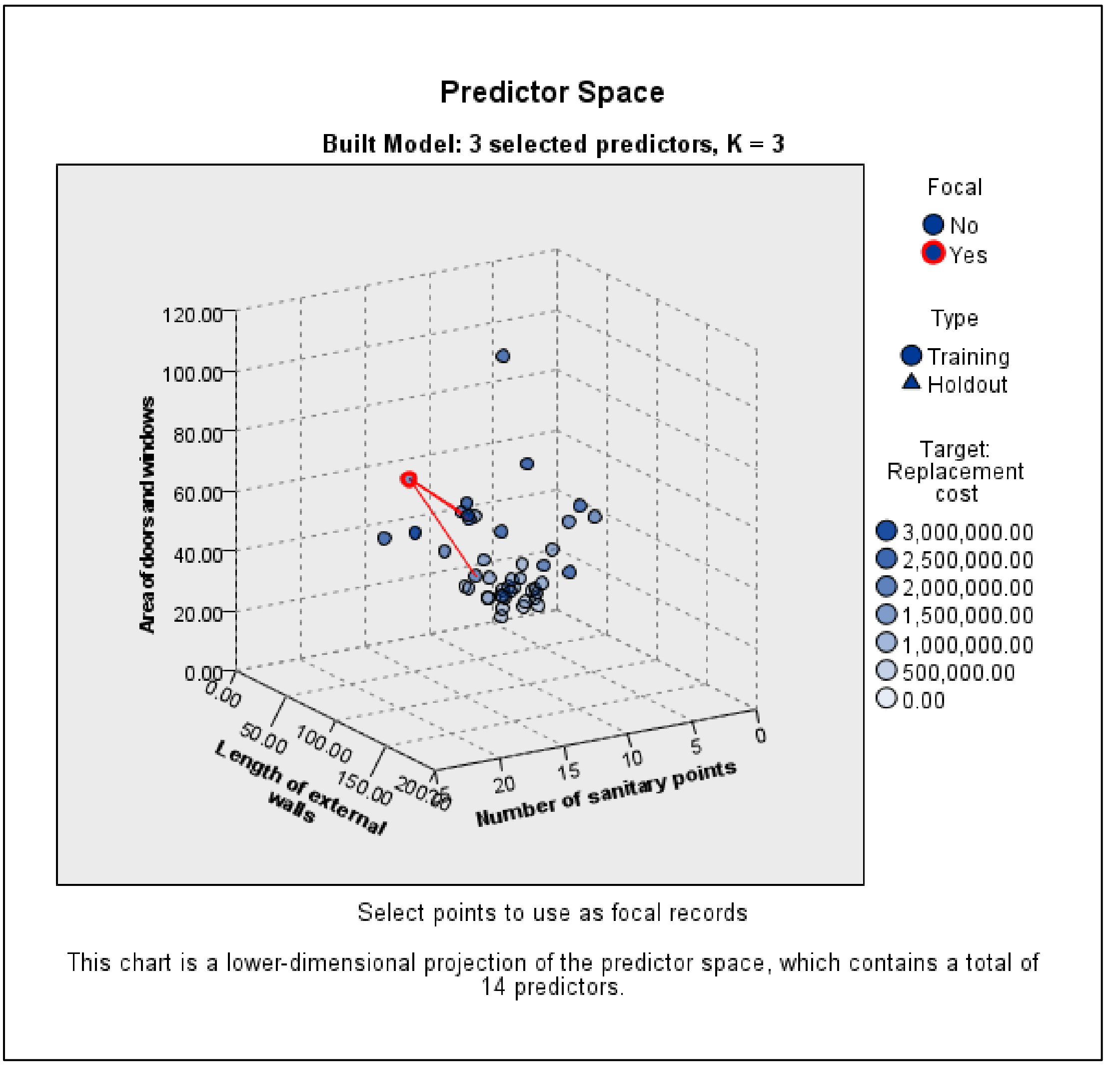

Figure 7.46: Predictor space for case 7 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.58: Nearest neighbours for case 7 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
7	34	21	39	0.239	0.287	0.354

7.2.5.2.8 Case 8

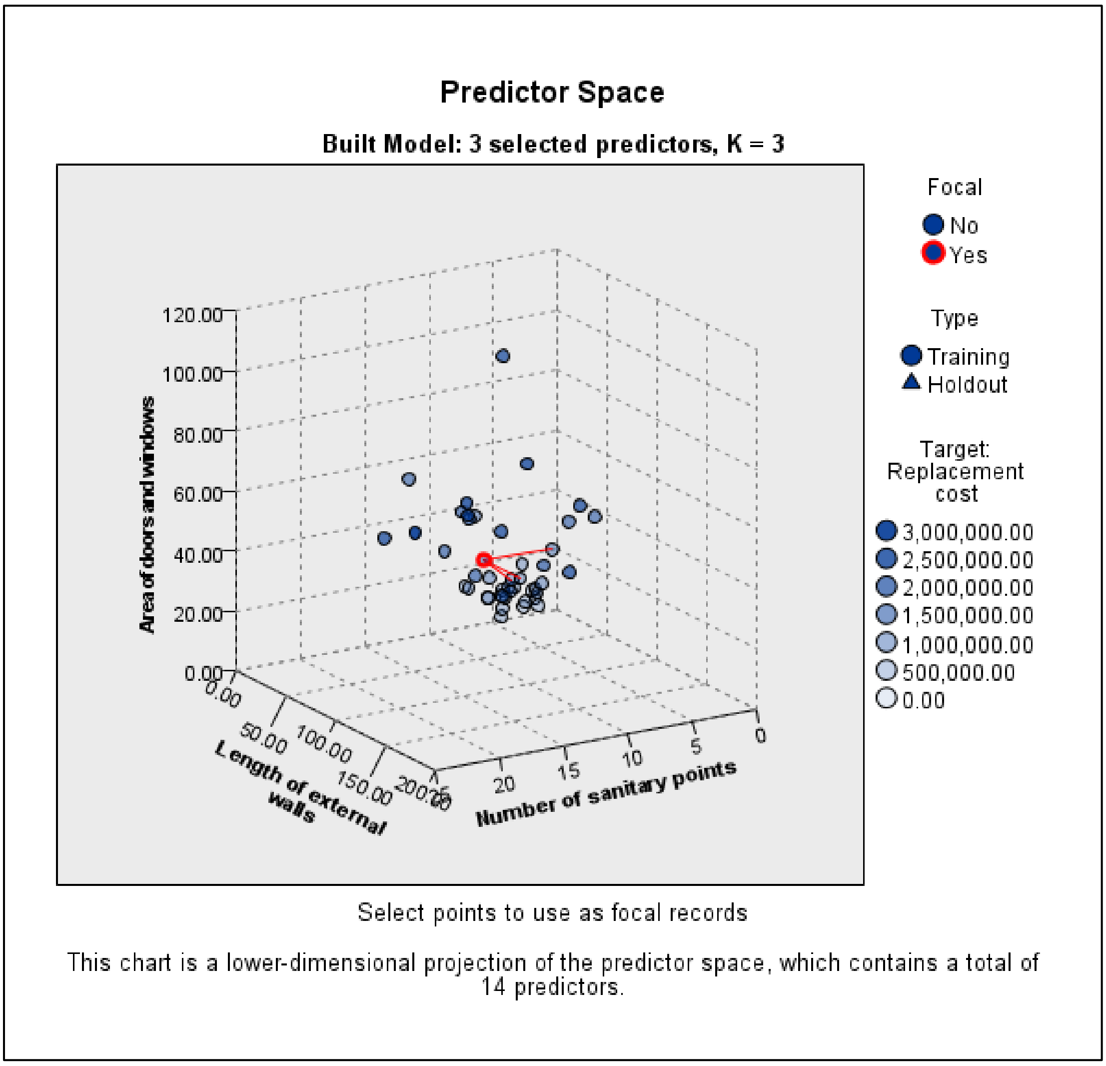

Figure 7.47: Predictor space for case 8 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.59: Nearest neighbours for case 8 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
8	42	32	9	0.232	0.269	0.273

7.2.5.2.9 Case 9

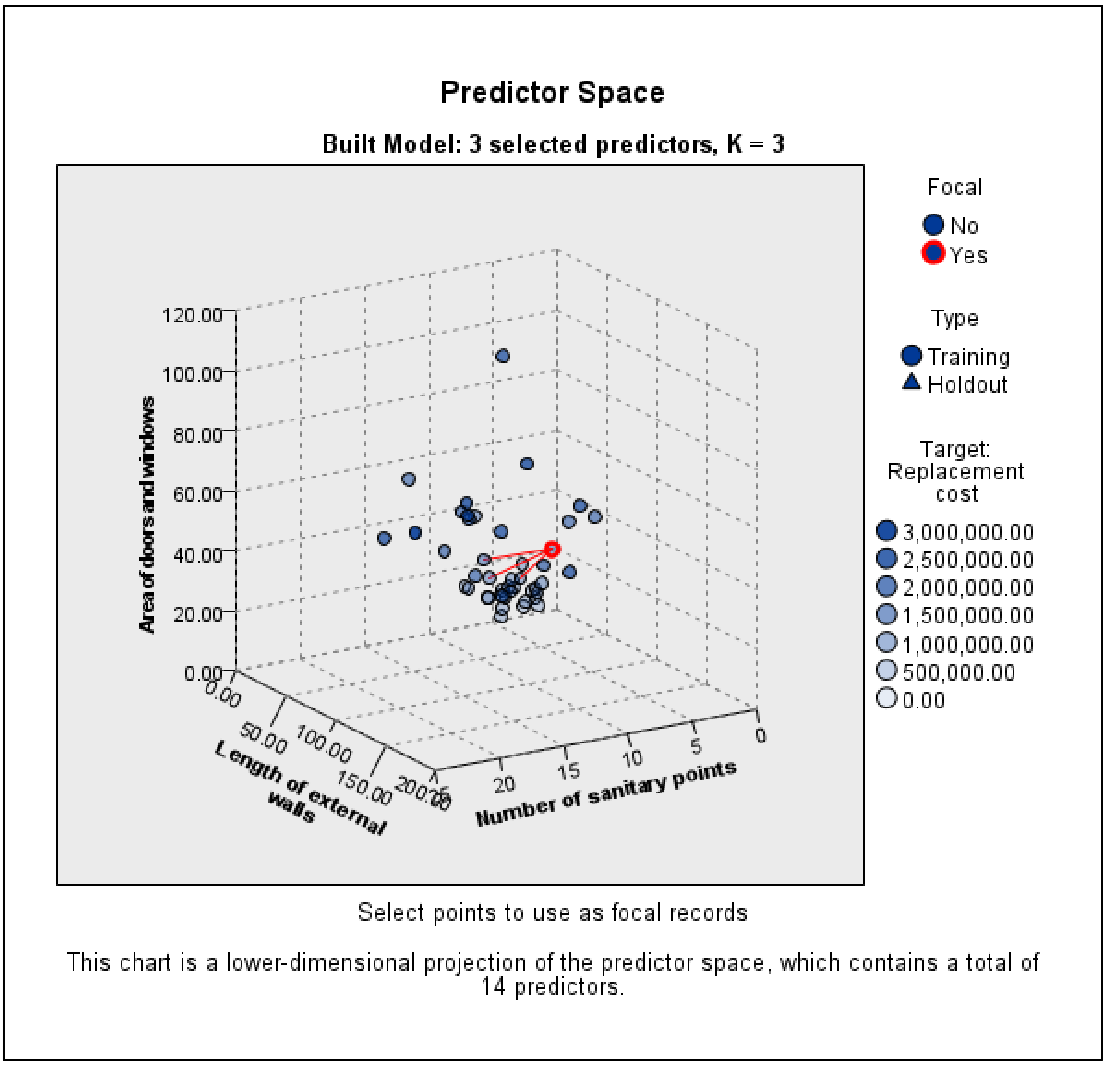

Figure 7.48: Predictor space for case 9 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.60: Nearest neighbours for case 9 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
9	42	17	8	0.210	0.273	0.273

7.2.5.2.10 Case 10

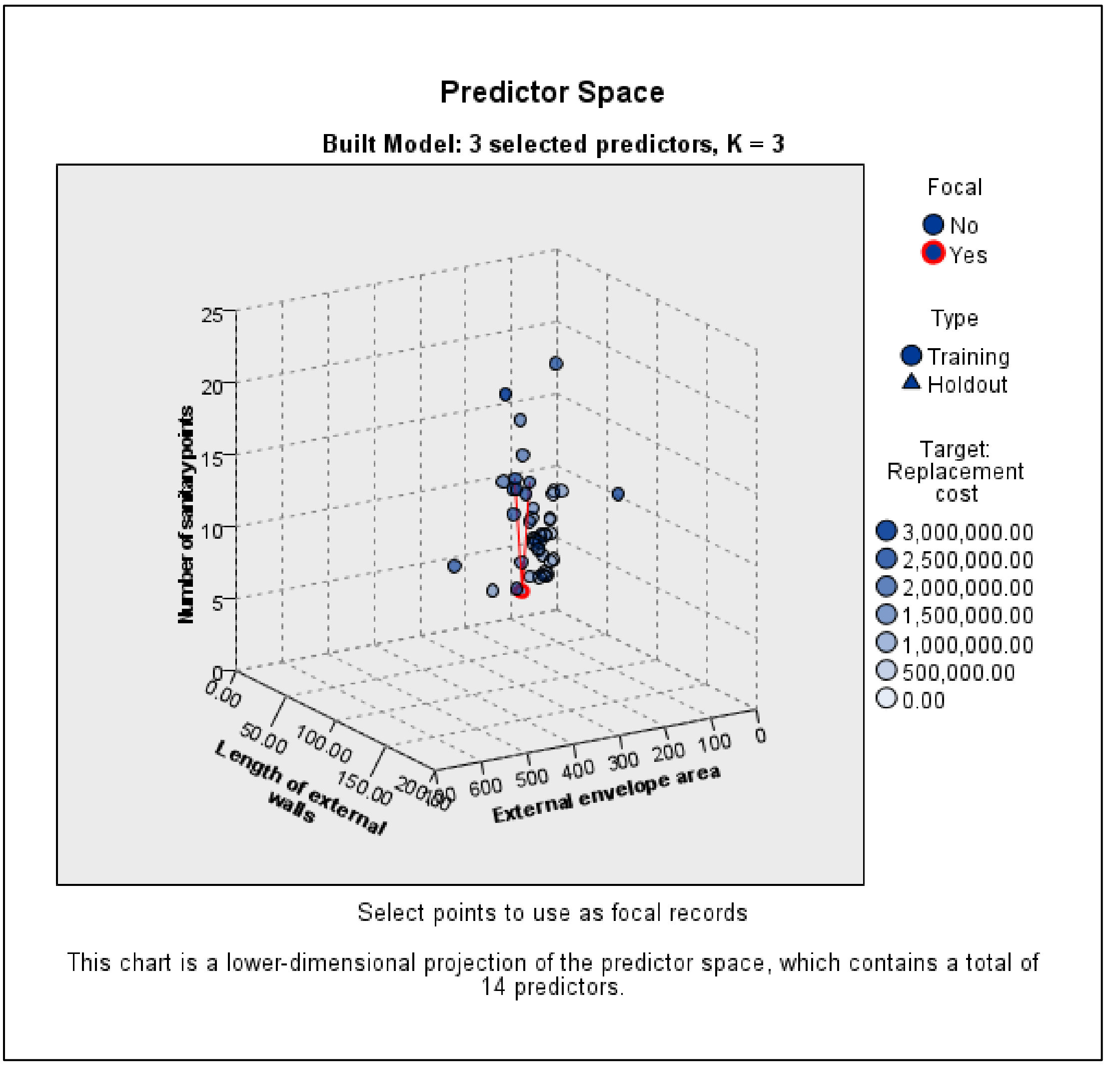

Figure 7.49: Predictor space for case 10 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.61: Nearest neighbours for case 10 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
10	20	39	16	0.340	0.343	0.393

7.2.5.2.11 Case 11

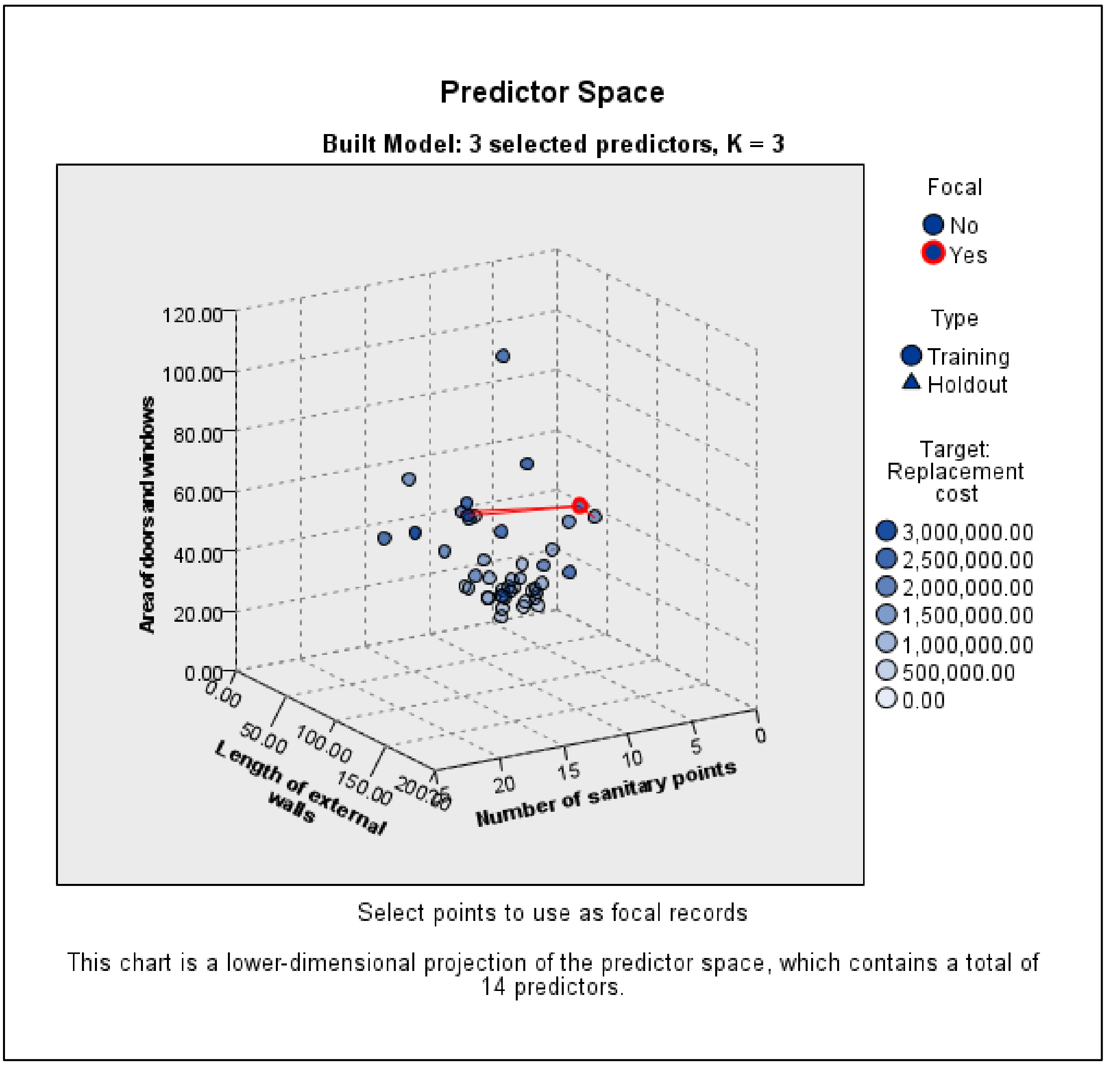

Figure 7.50: Predictor space for case 11 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.62: Nearest neighbours for case 11 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
11	16	38	34	0.364	0.451	0.452

7.2.5.2.12 Case 12

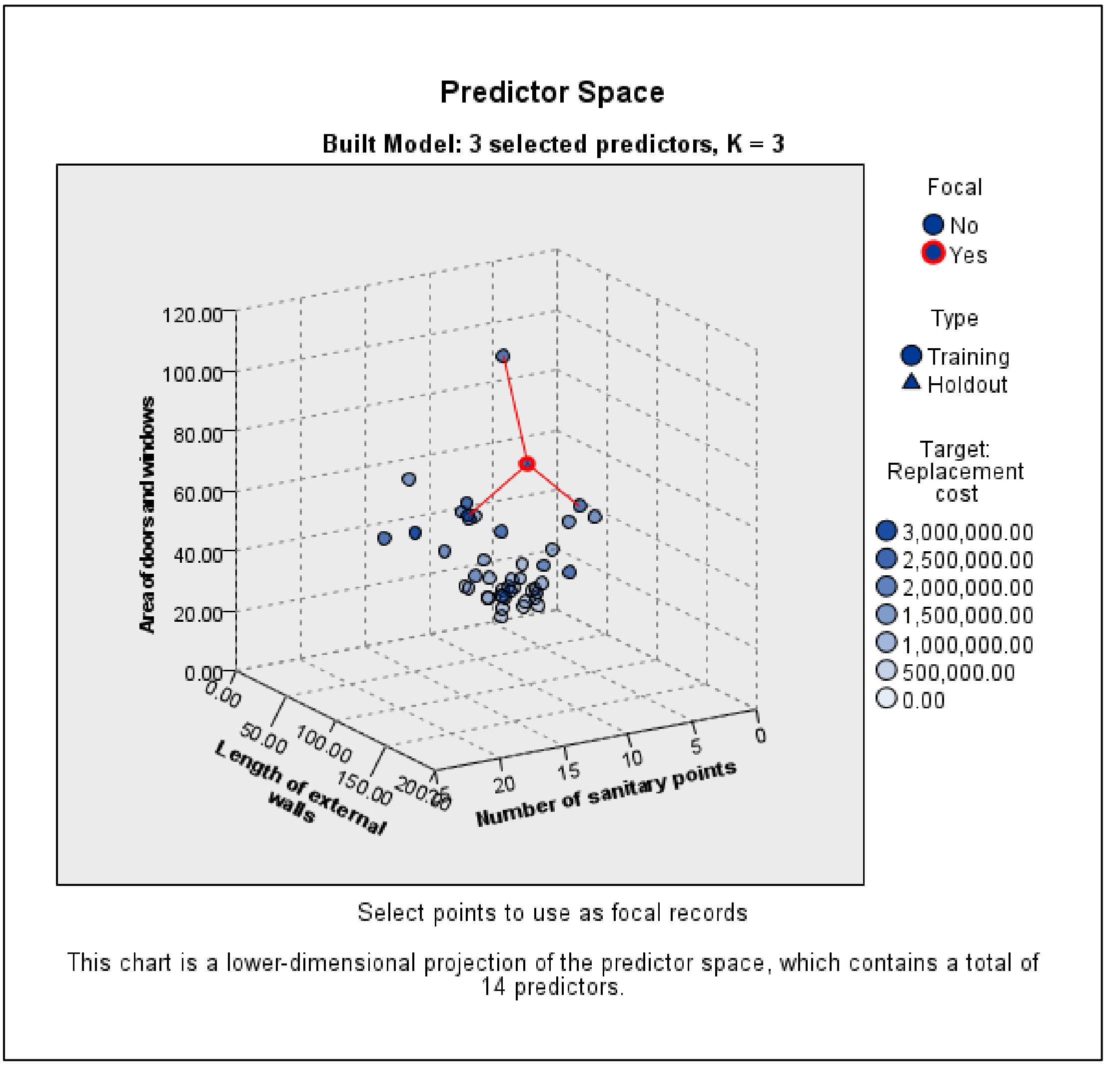

Figure 7.60: Predictor space for case 12 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.63: Nearest neighbours for case 12 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
12	11	16	13	0.471	0.515	0.597

7.2.5.2.13 Case 13

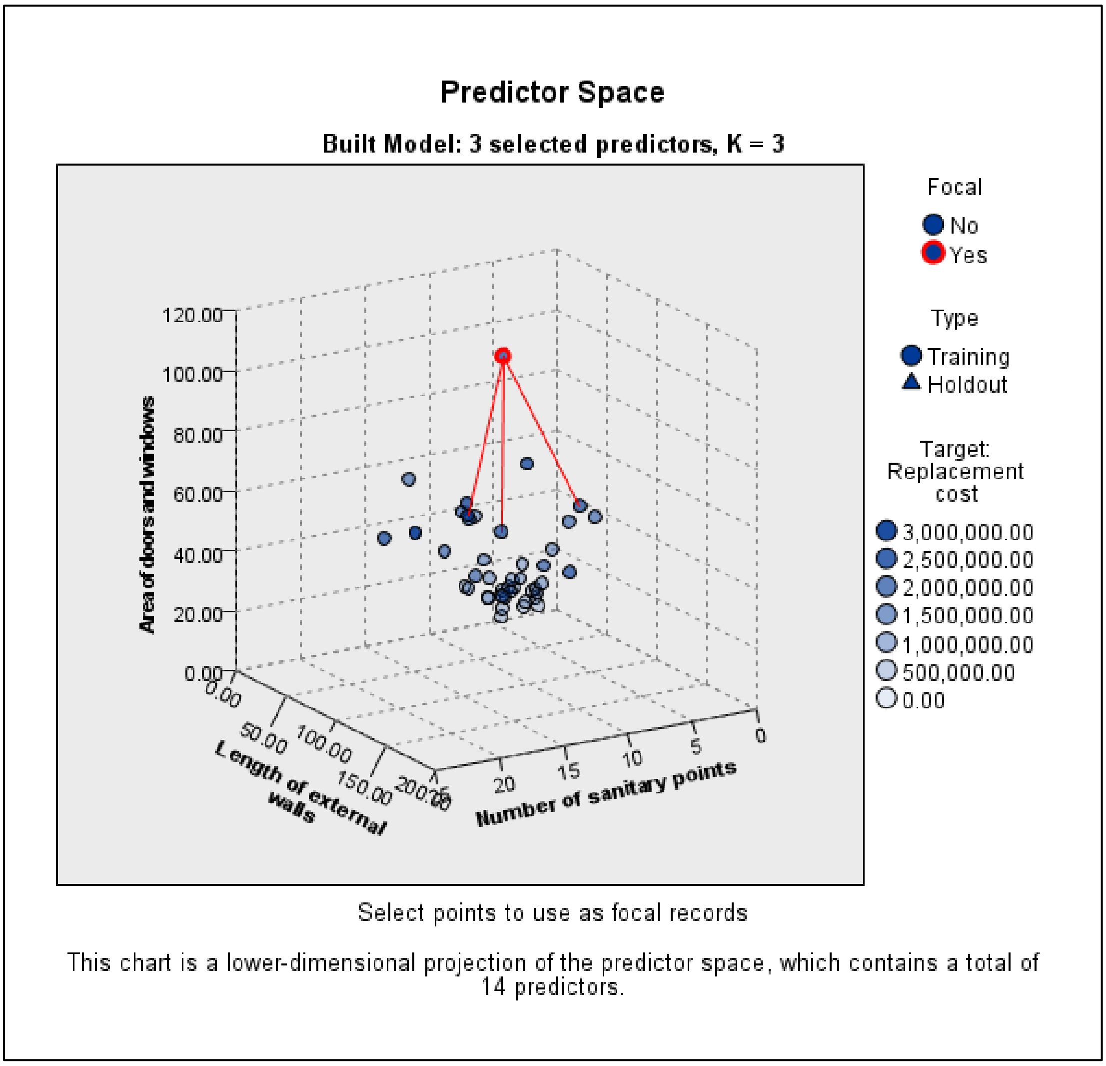

Figure 7.51: Predictor space for case 13 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.64: Nearest neighbours for case 13 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
13	16	19	11	0.472	0.496	0.570

7.2.5.2.14 Case 14

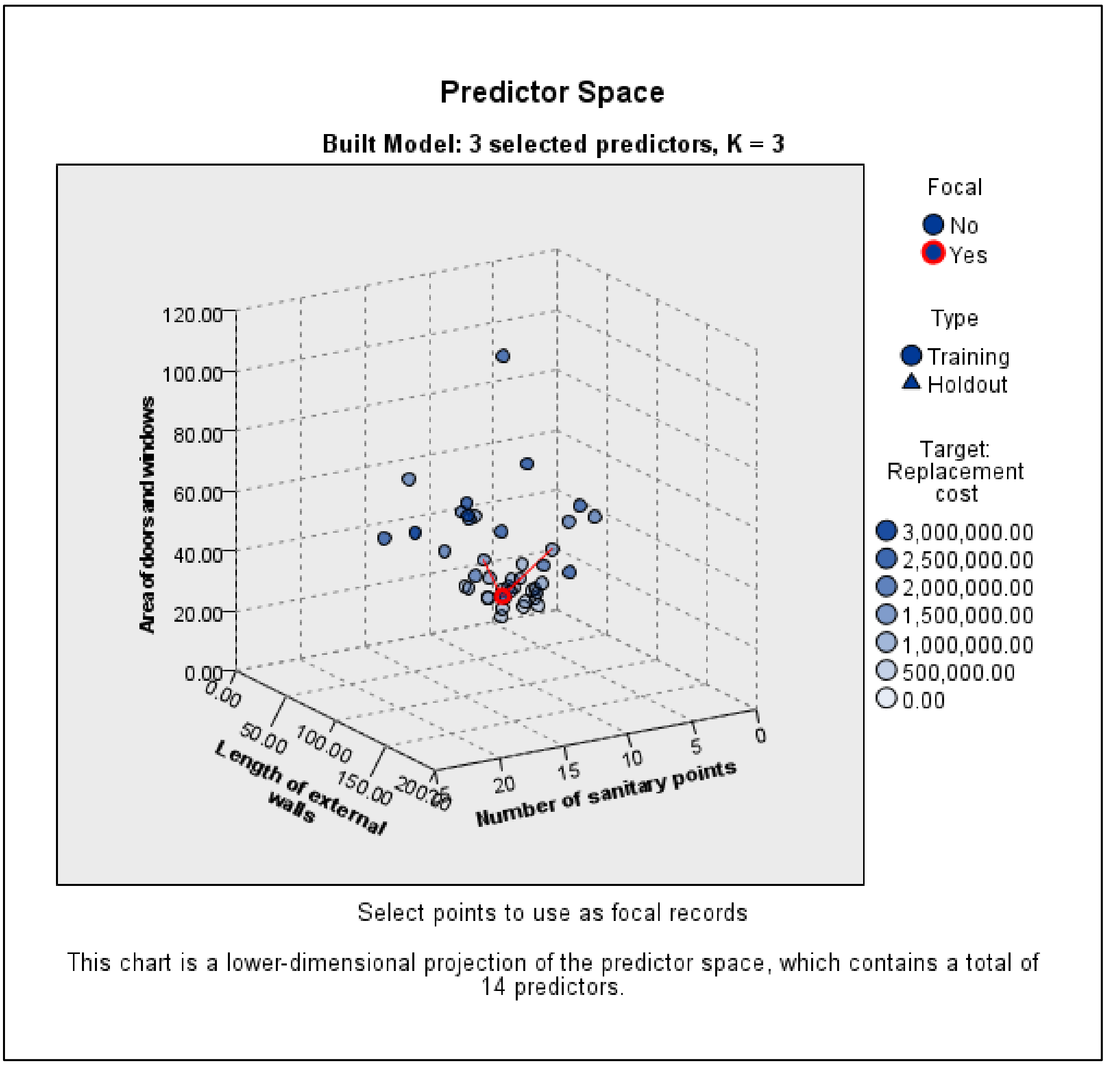

Figure 7.52: Predictor space for case 14 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.65: Nearest neighbours for case 14 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
14	9	8	42	0.334	0.338	0.366

7.2.5.2.15 Case 15

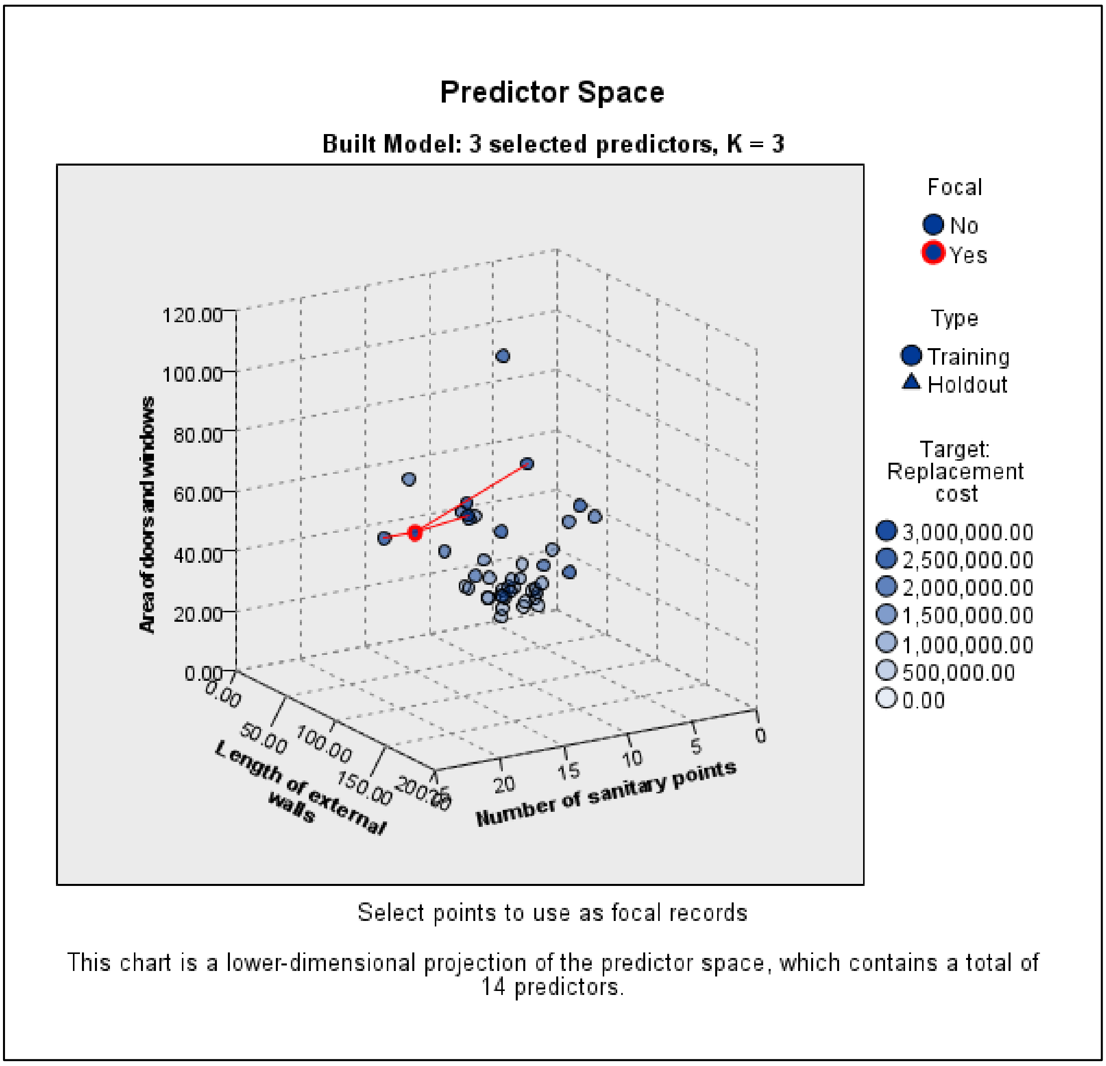

Figure 7.53: Predictor space for case 15 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.66: Nearest neighbours for case 15 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
15	22	12	16	0.512	0.598	0.694

7.2.5.2.16 Case 16

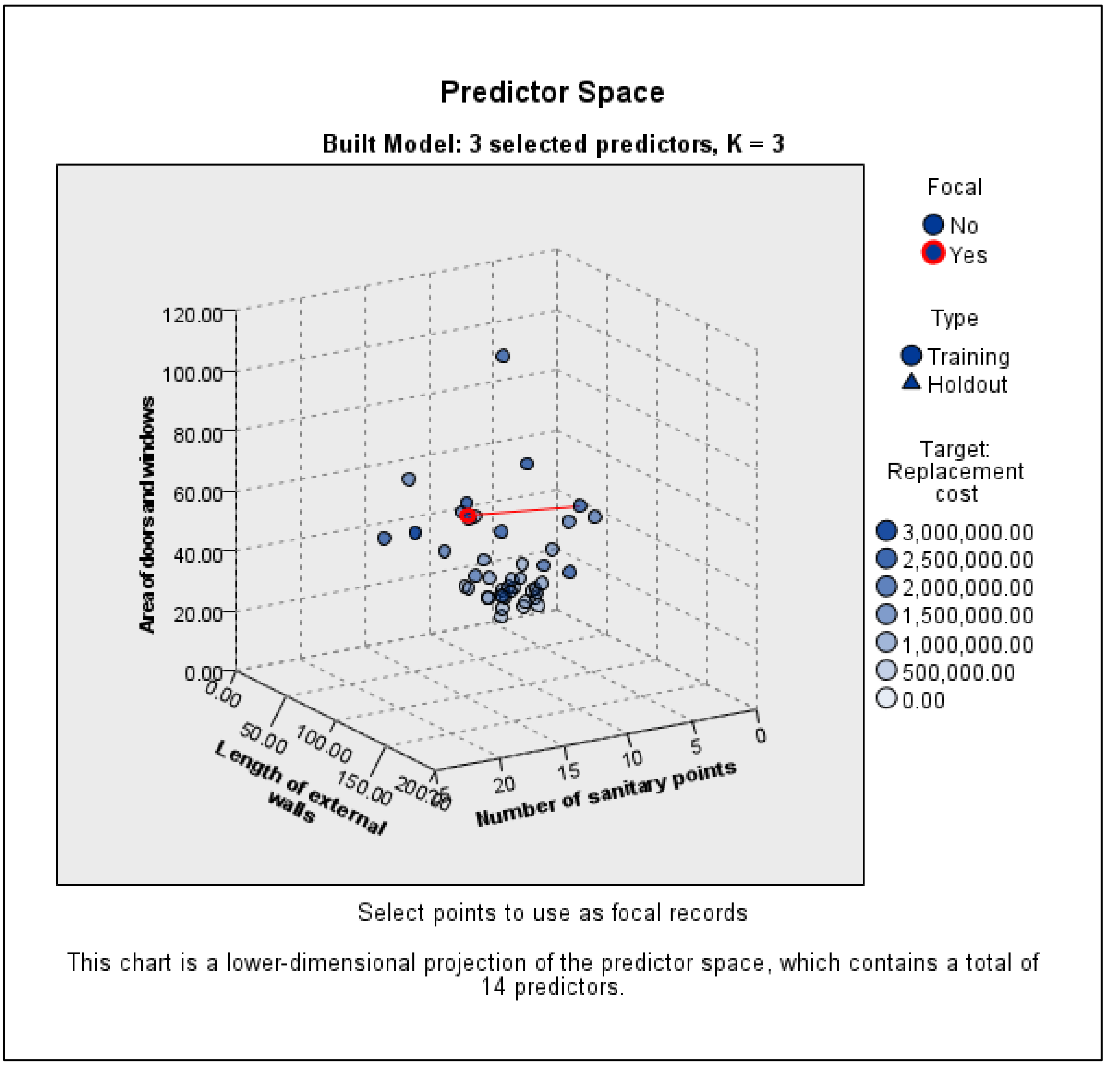

Figure 7.54: Predictor space for case 16 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.67: Nearest neighbours for case 16 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
16	34	11	39	0.343	0.364	0.367

7.2.5.2.17 Case 17

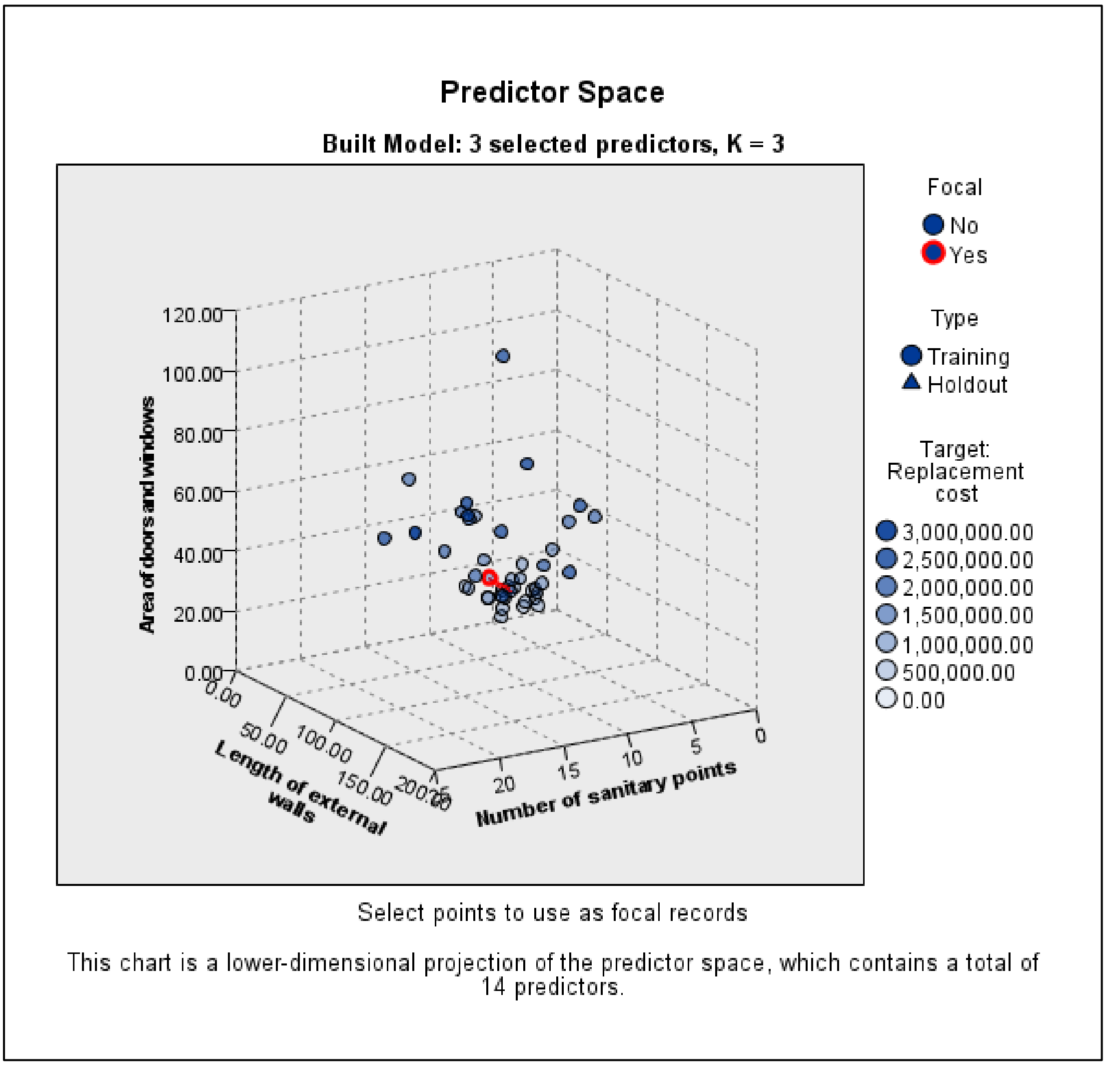

Figure 7.55: Predictor space for case 17 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.68: Nearest neighbours for case 17 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
17	31	30	28	0.165	0.177	0.184

7.2.5.2.18 Case 18

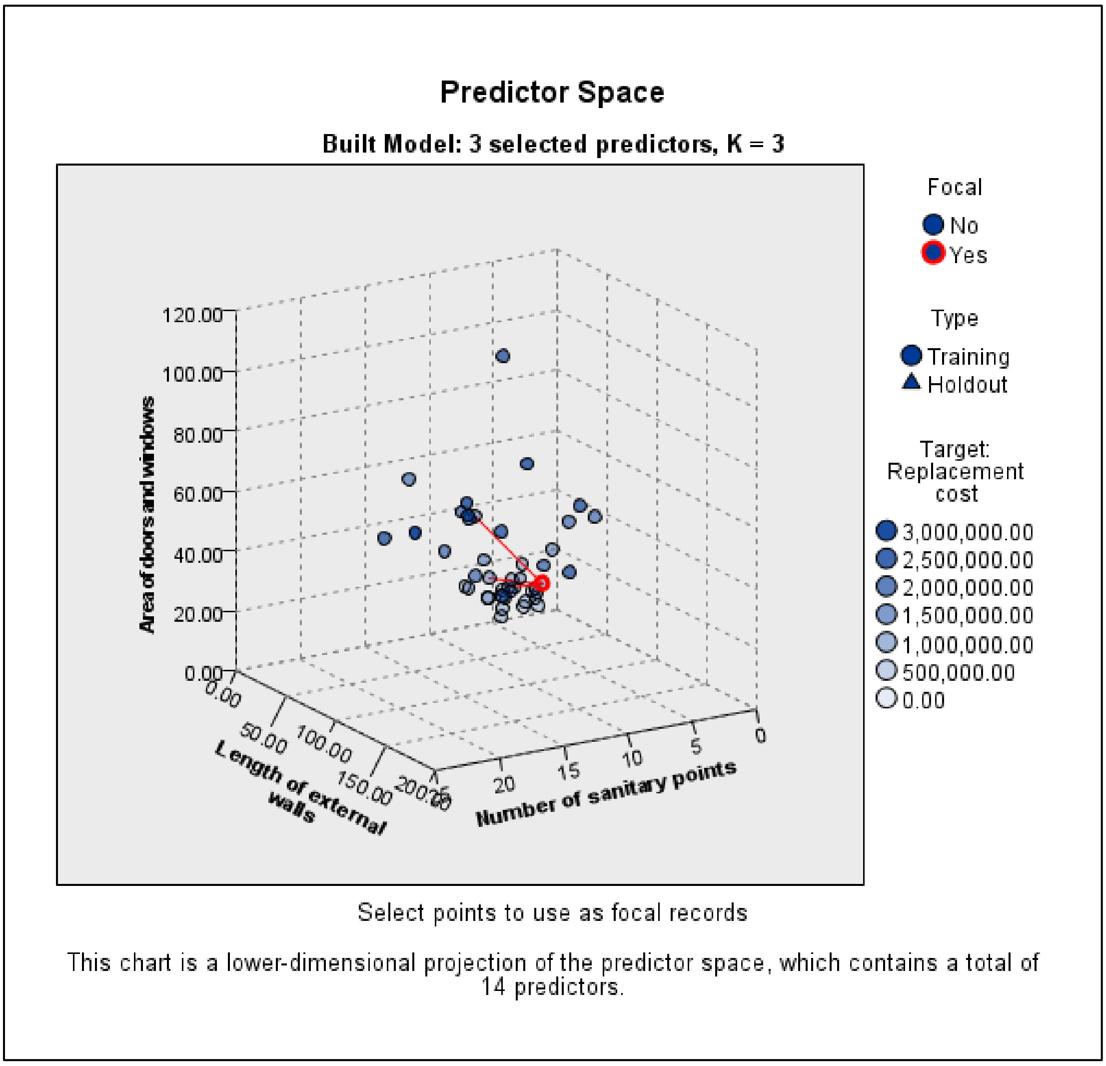

Figure 7.56: Predictor space for case 18 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.69: Nearest neighbours for case 18 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
18	17	33	31	0.288	0.330	0.390

7.2.5.2.19 Case 19

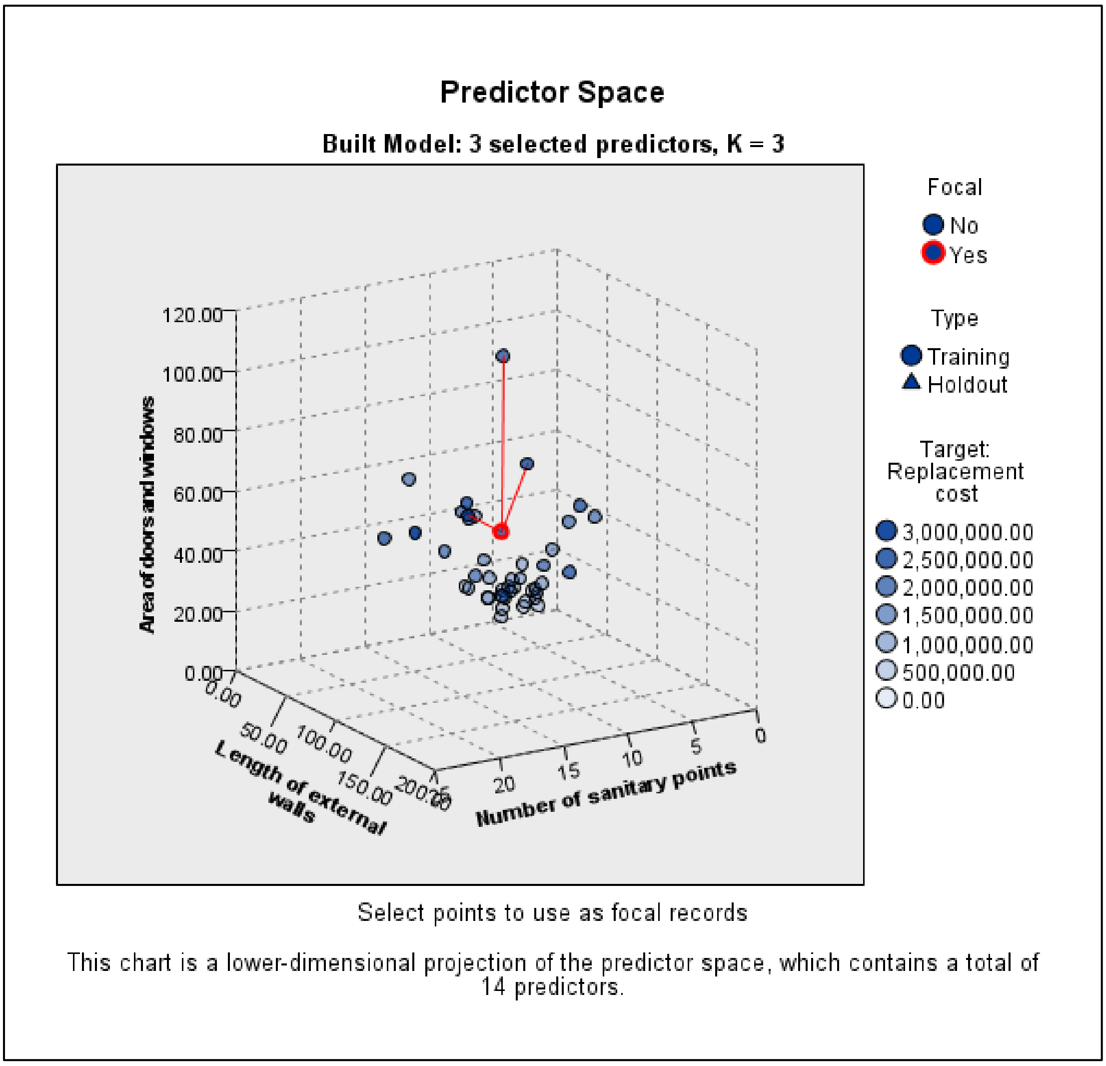

Figure 7.57: Predictor space for case 19 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.70: Nearest neighbours for case 19 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
19	13	12	16	0.496	0.598	0.609

7.2.5.2.20 Case 20

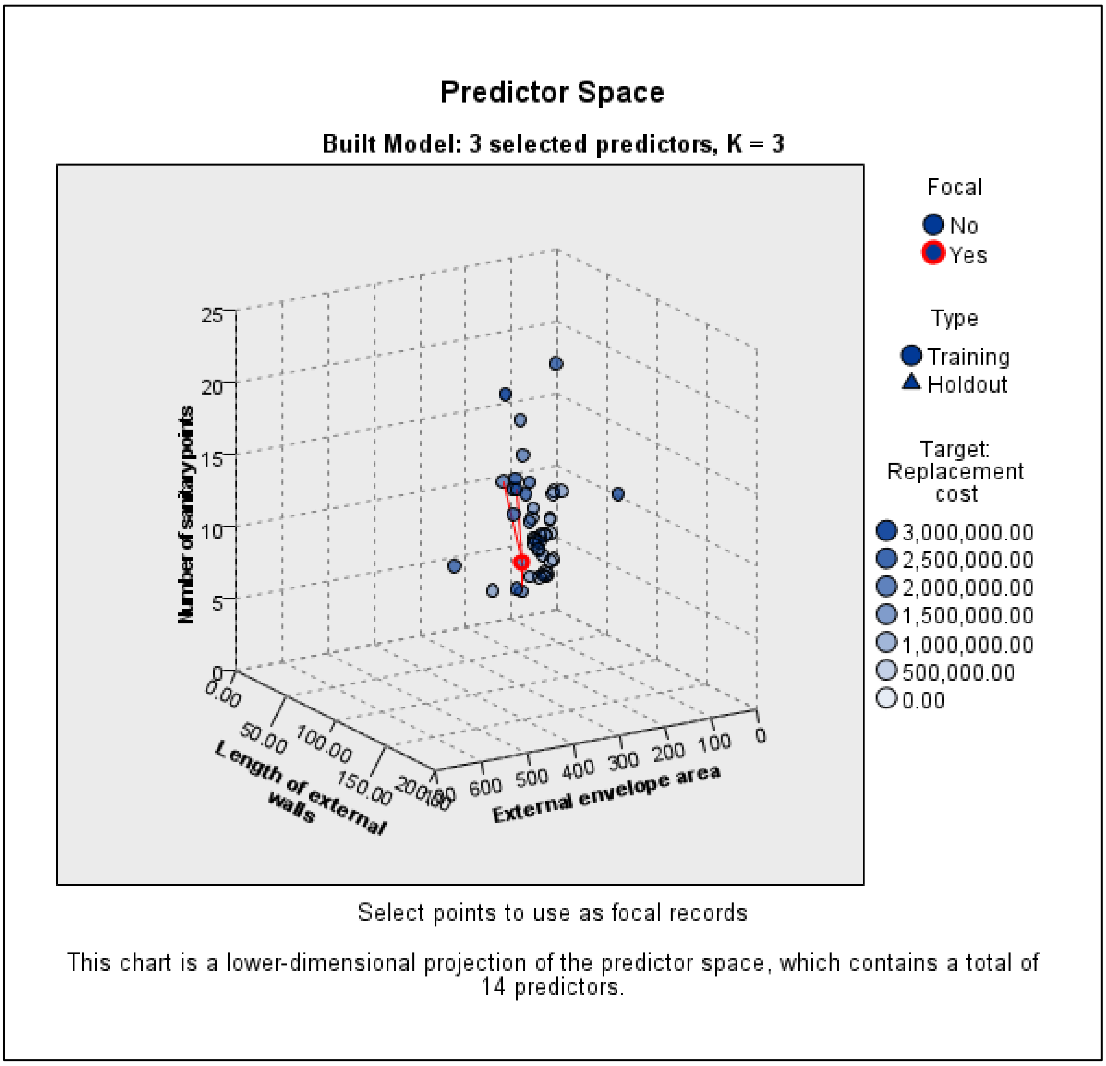

Figure 7.58: Predictor space for case 20 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.71: Nearest neighbours for case 20 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
20	21	34	10	0.321	0.337	0.338

7.2.5.2.21 Case 21

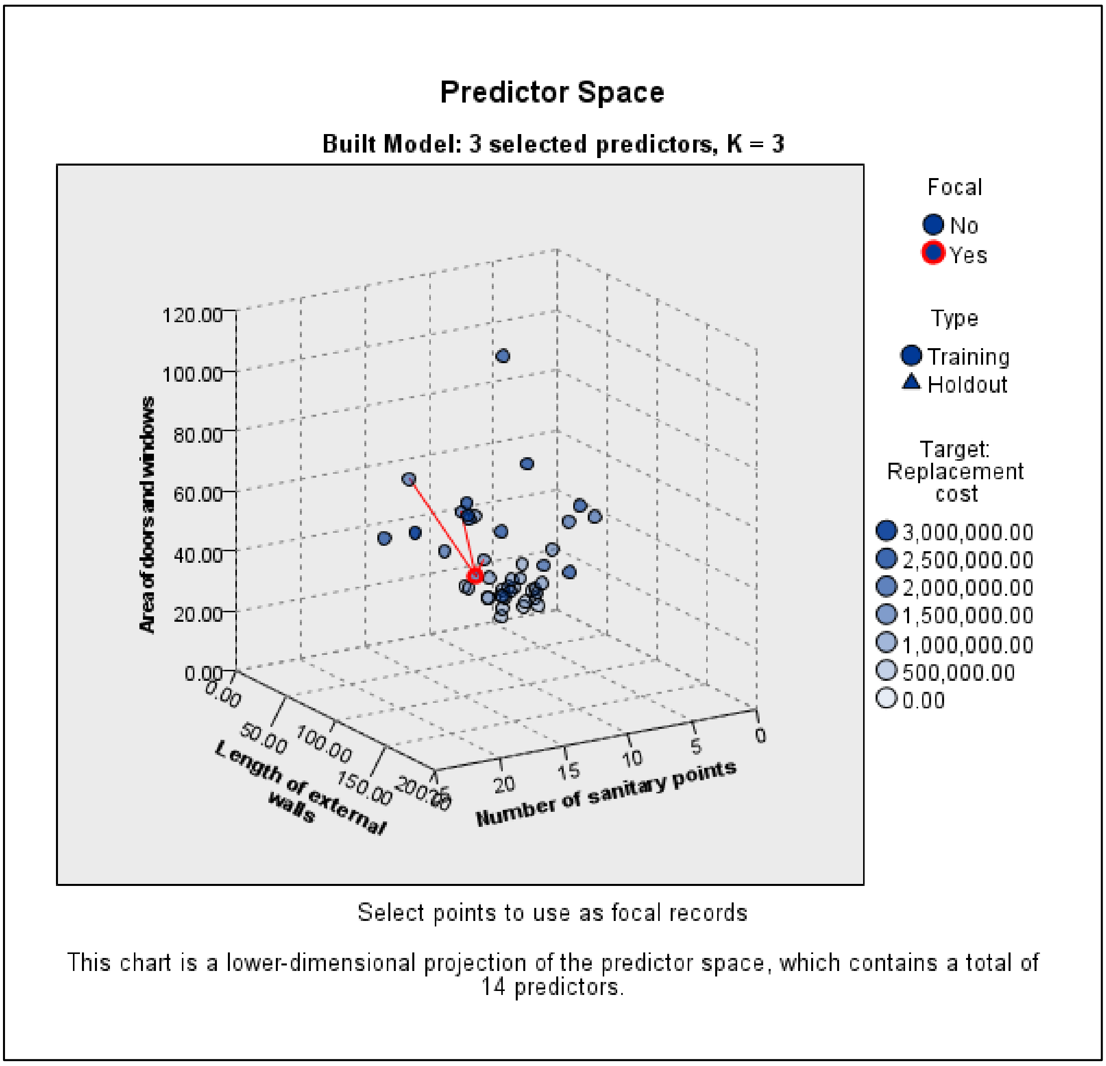

Figure 7.59: Predictor space for case 21 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.72: Nearest neighbours for case 21 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
21	7	8	34	0.287	0.290	0.309

7.2.5.2.22 Case 22

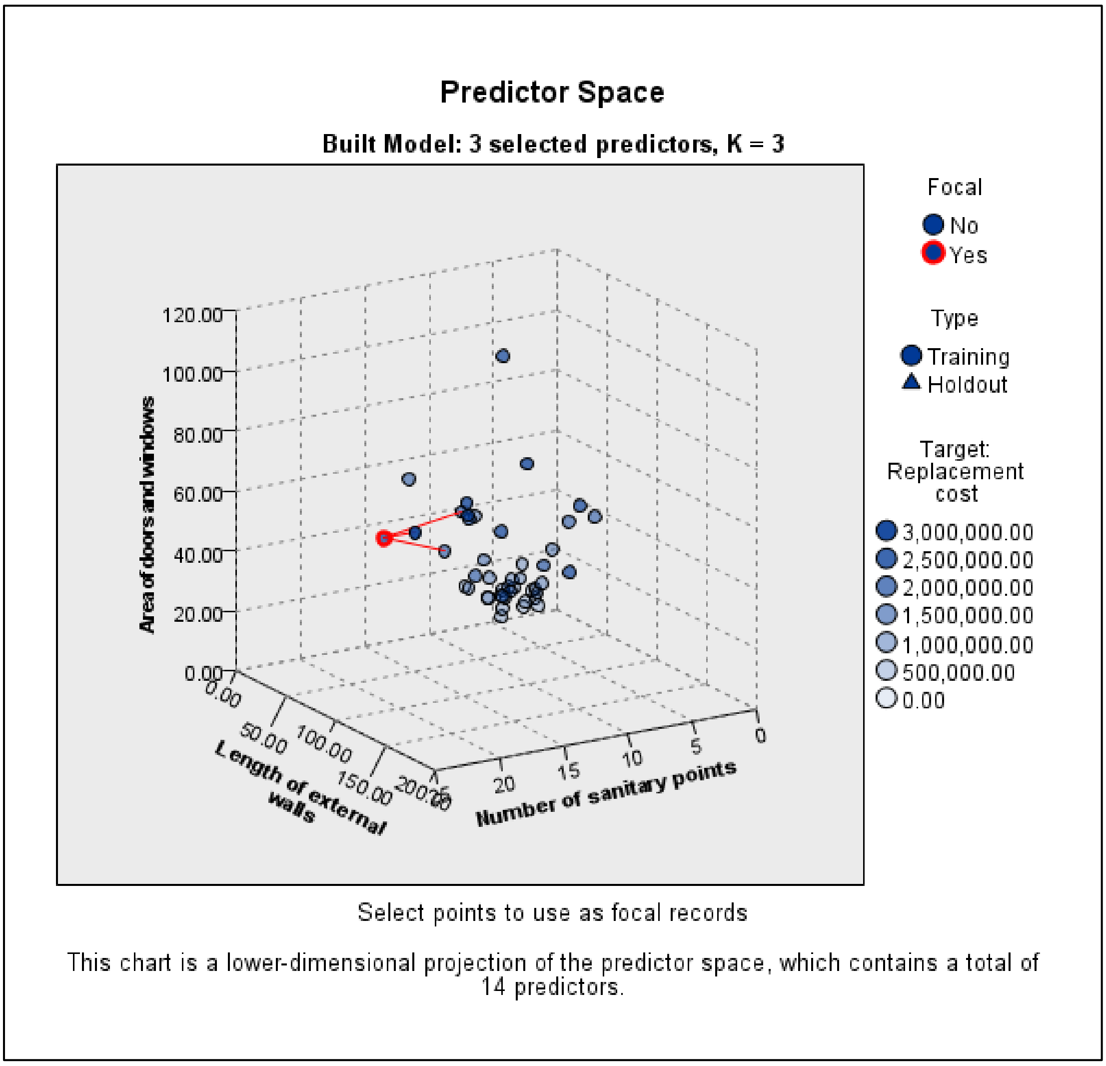

Figure 7.70: Predictor space for case 22 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.73: Nearest neighbours for case 22 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
22	41	15	34	0.428	0.512	0.534

7.2.5.2.23 Case 23

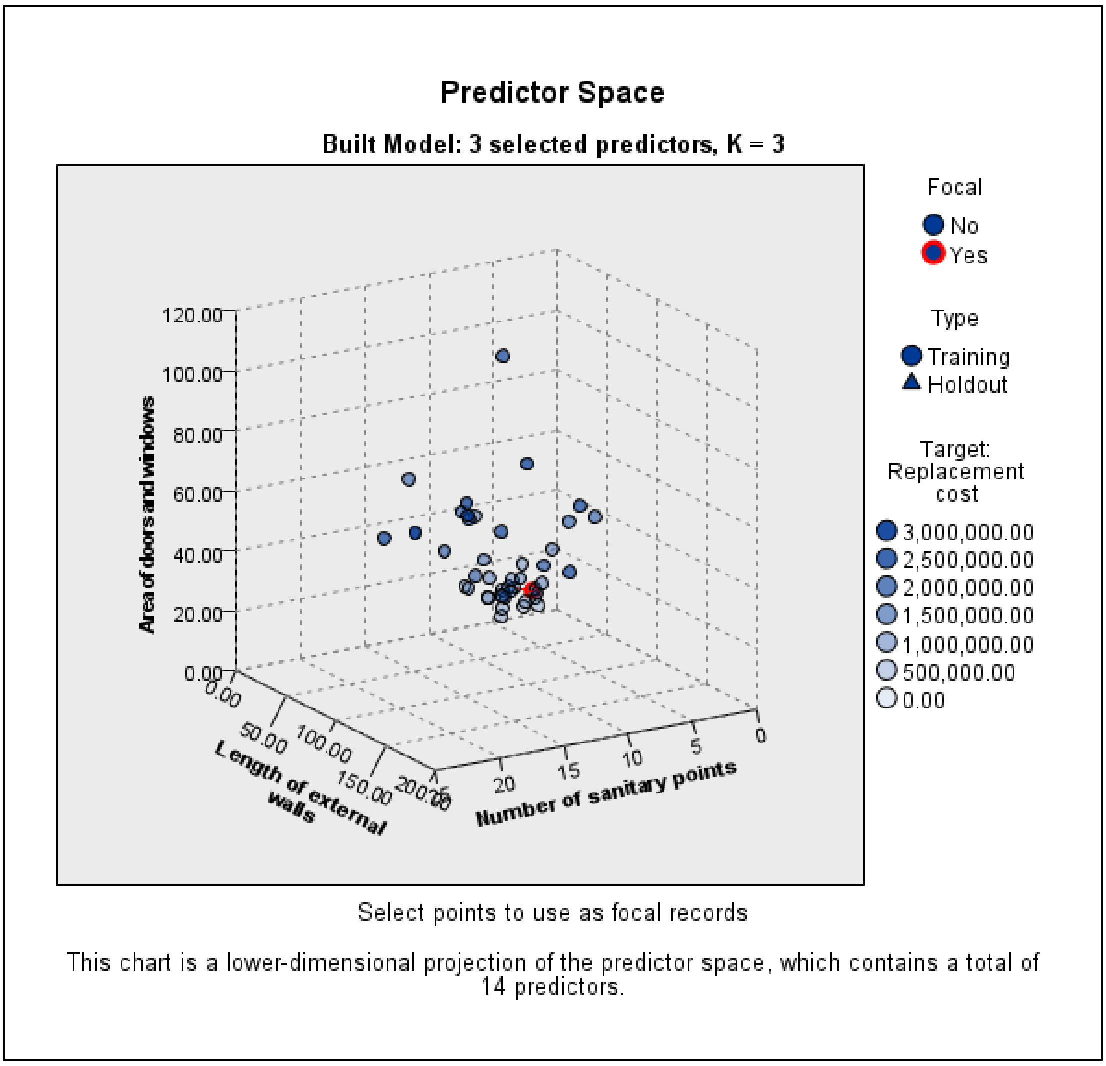

Figure 7.60: Predictor space for case 23 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.74: Nearest neighbours for case 23 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
23	24	43	36	0.025	0.090	0.121

7.2.5.2.24 Case 24

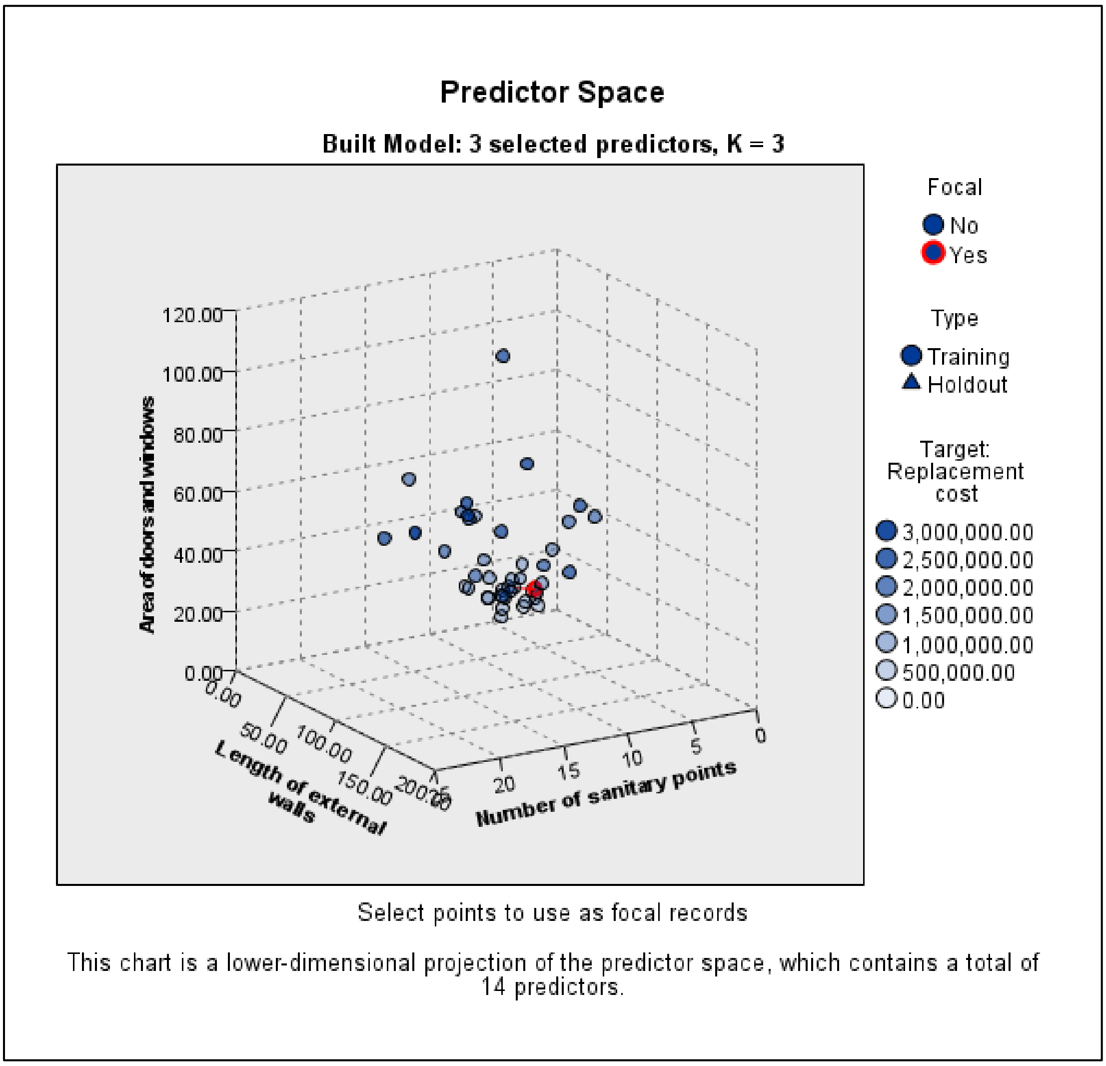

Figure 7.61: Predictor space for case 24 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.75: Nearest neighbours for case 24 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
24	23	43	36	0.025	0.094	0.106

7.2.5.2.25 Case 25

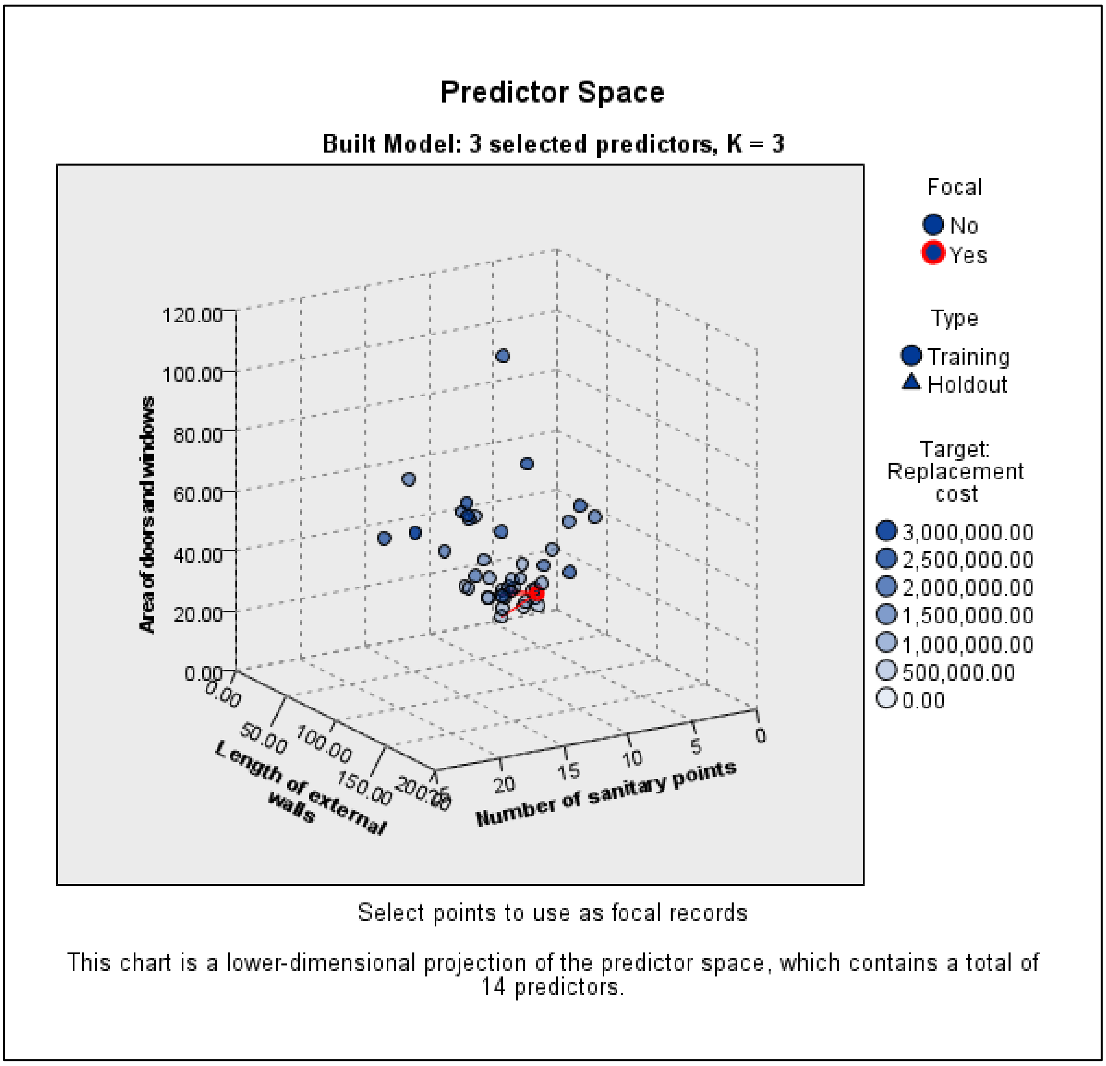

Figure 7.62: Predictor space for case 25 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.76: Nearest neighbours for case 25 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
25	27	28	26	0.092	0.101	0.108

7.2.5.2.26 Case 26

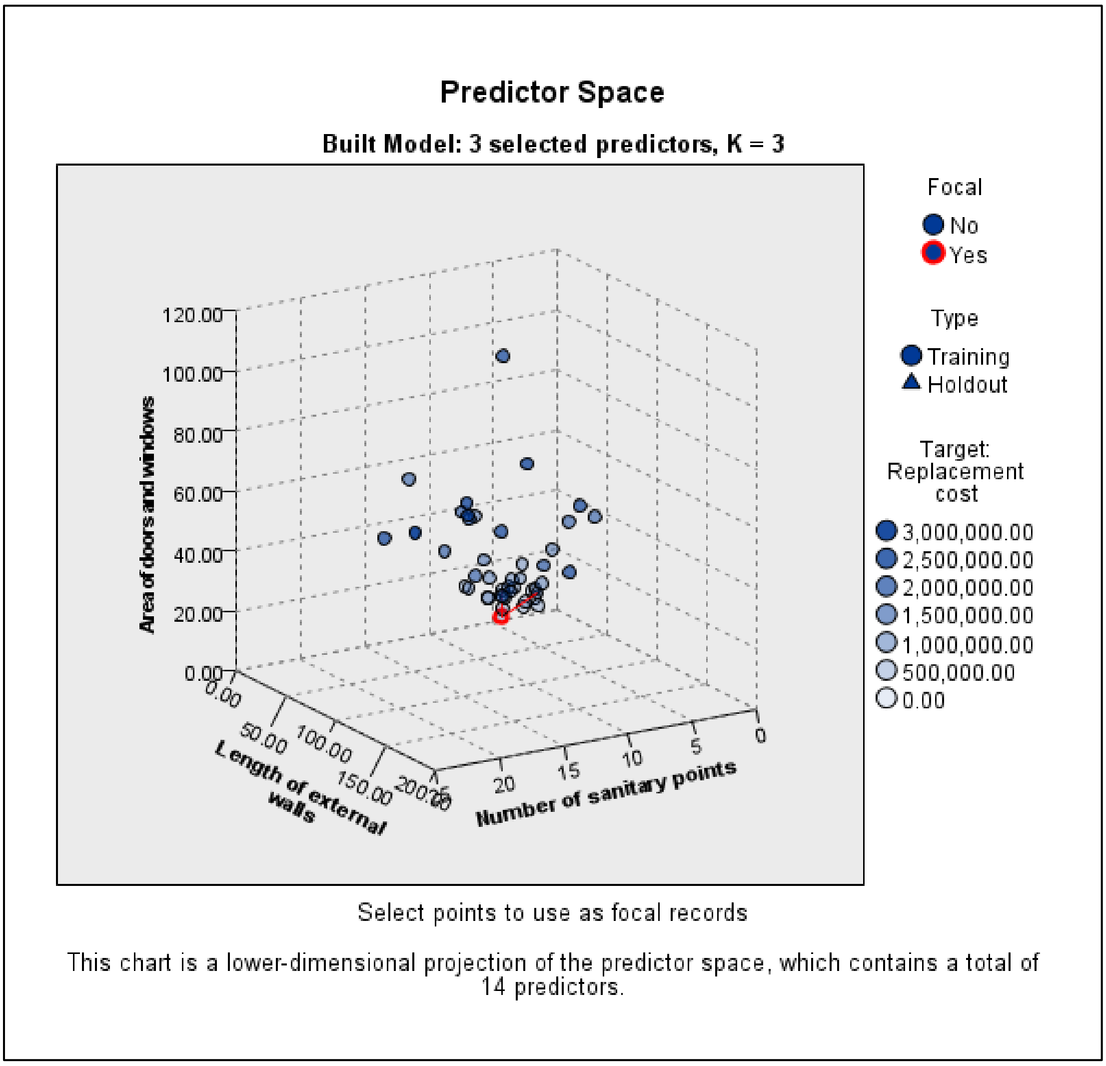

Figure 7.63: Predictor space for case 26 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.77: Nearest neighbours for case 26 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
26	27	28	25	0.073	0.090	0.108

7.2.5.2.27 Case 27

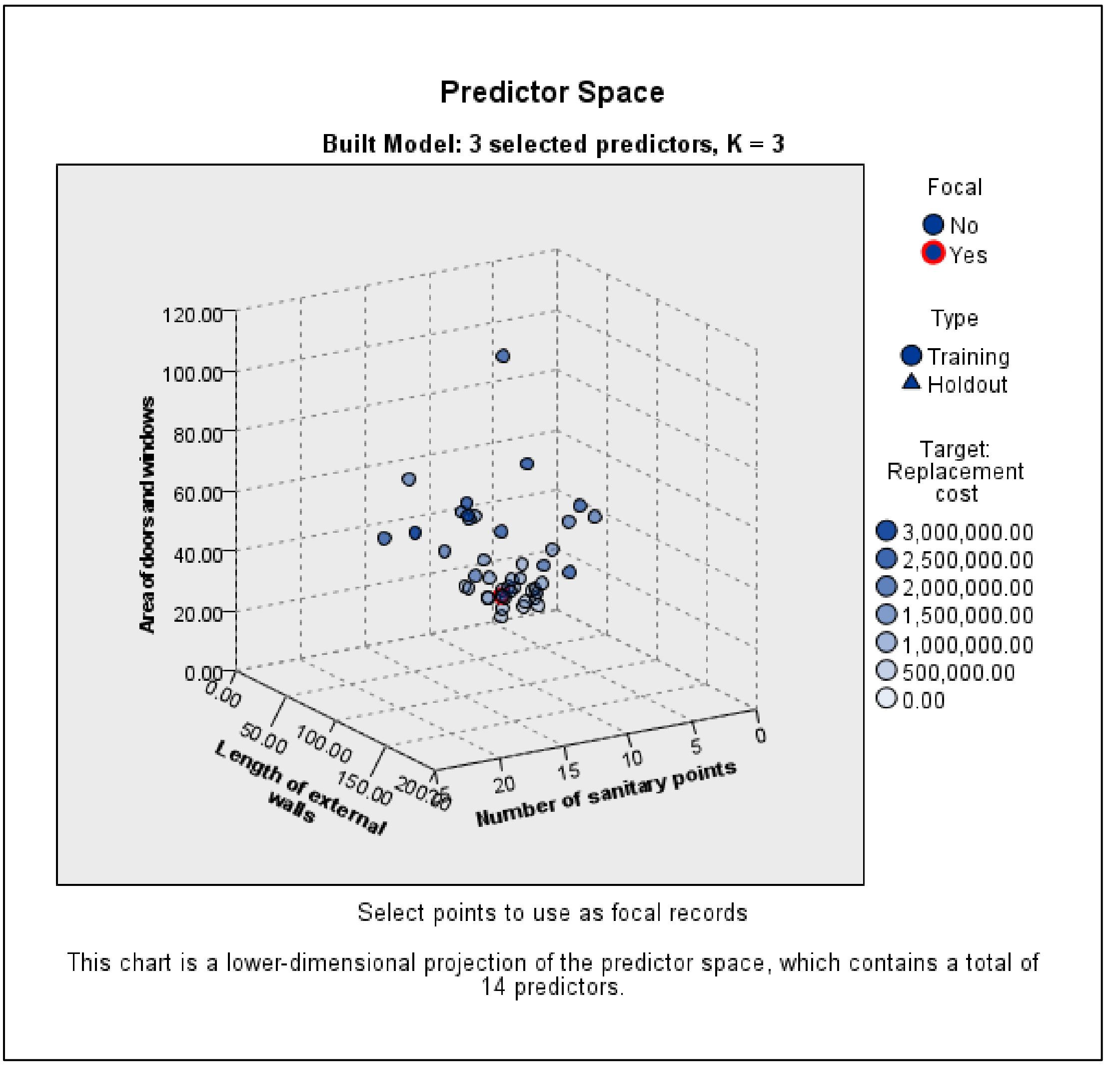

Figure 7.64: Predictor space for case 27 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.78: Nearest neighbours for case 27 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
27	28	31	29	0.031	0.060	0.068

7.2.5.2.28 Case 28

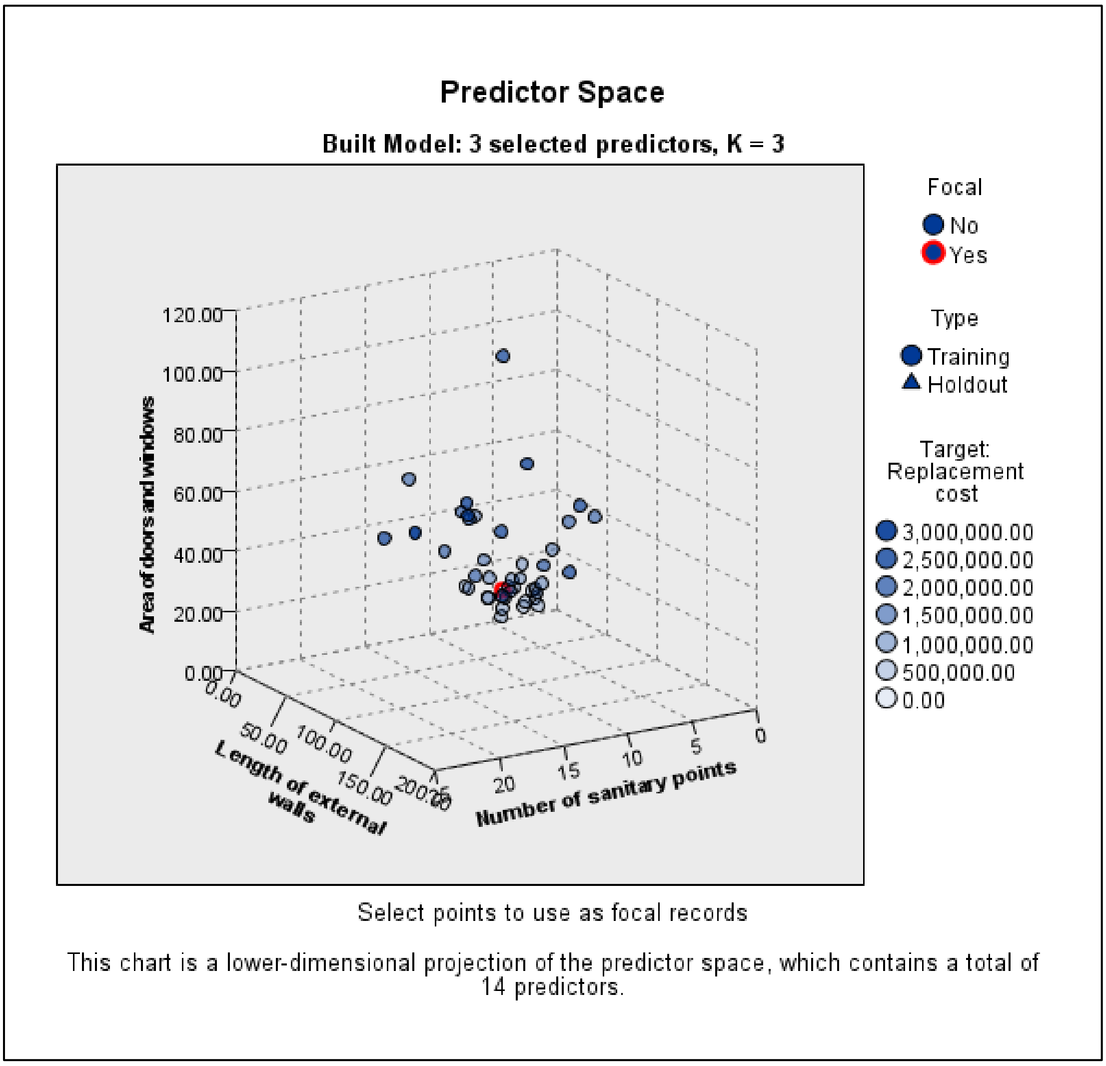

Figure 7.65: Predictor space for case 28 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.79: Nearest neighbours for case 28 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
28	27	31	29	0.031	0.043	0.066

7.2.5.2.29 Case 29

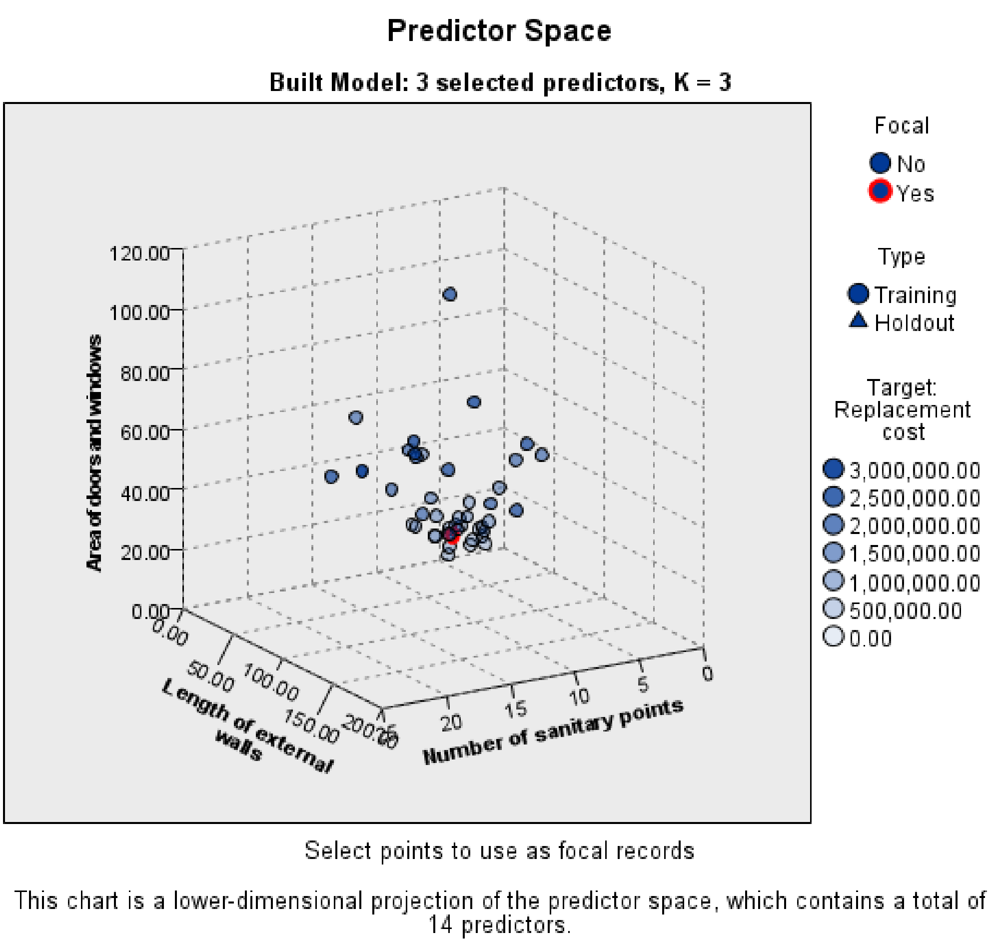

Figure 7.66: Predictor space for case 29 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.80: Nearest neighbours for case 29 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
29	30	31	28	0.050	0.064	0.066

7.2.5.2.30 Case 30

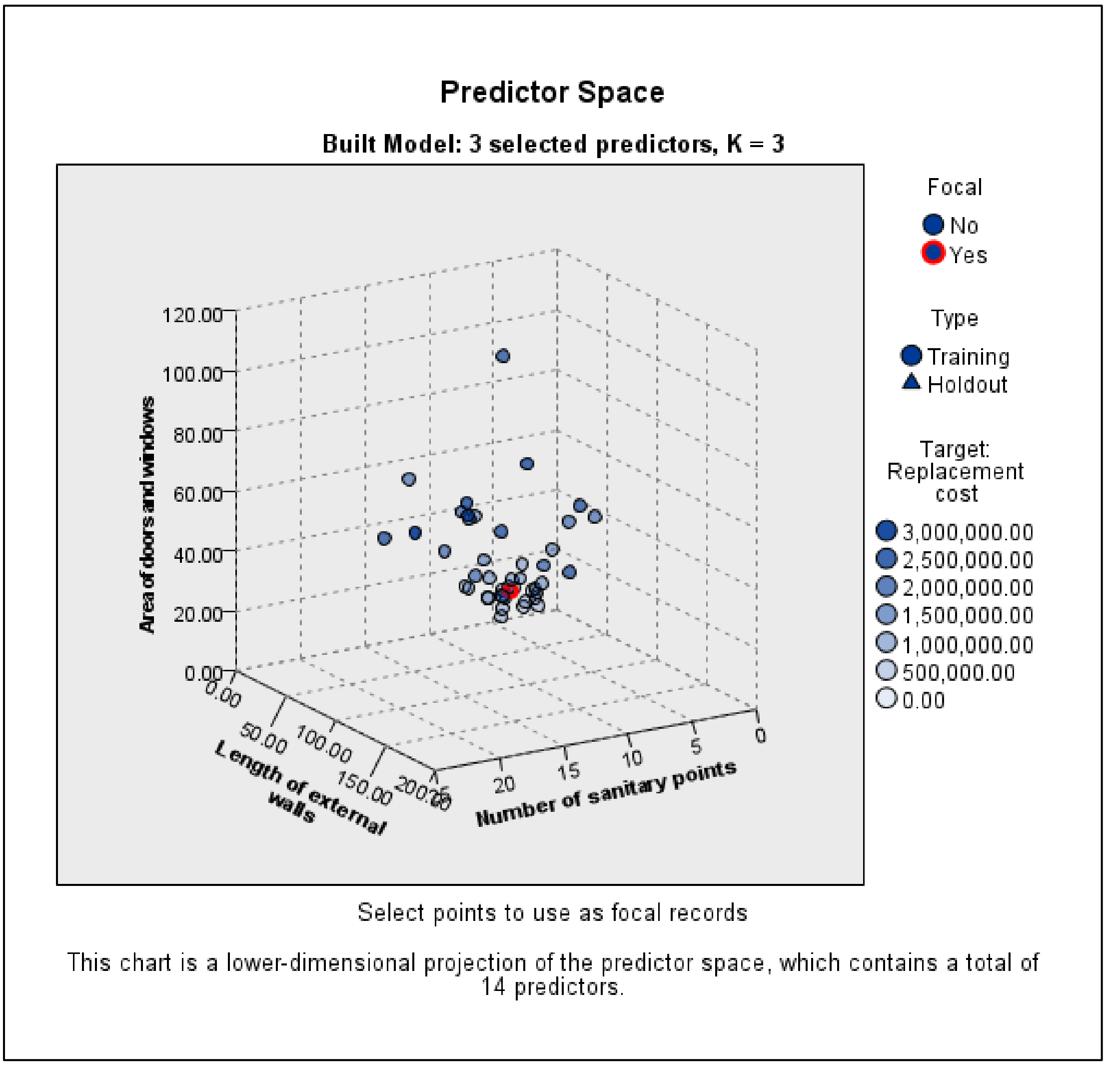

Figure 7.67: Predictor space for case 30 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.81: Nearest neighbours for case 30 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
30	29	31	28	0.050	0.067	0.077

7.2.5.2.31 Case 31

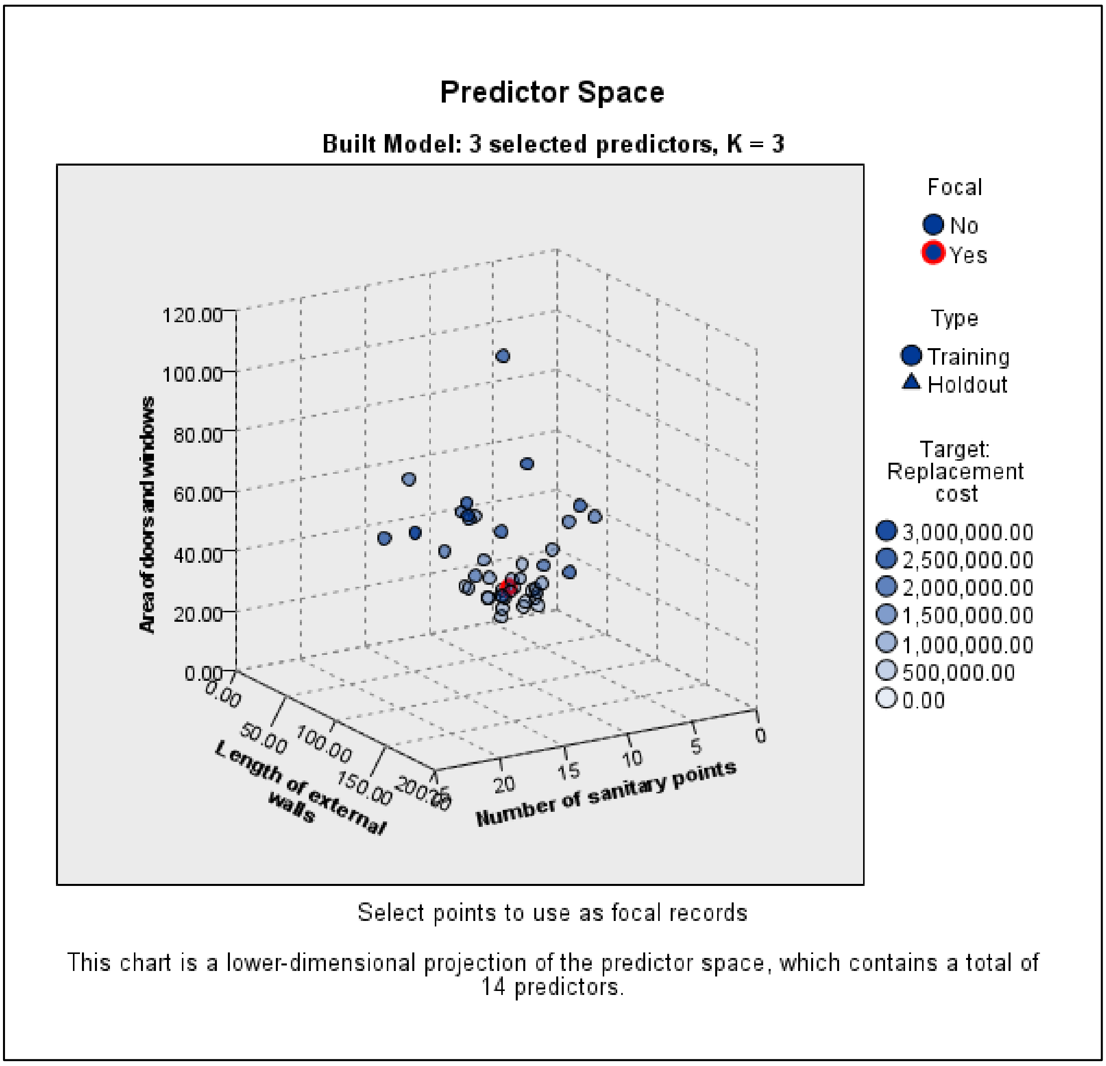

Figure 7.68: Predictor space for case 31 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.82: Nearest neighbours for case 31 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
31	28	27	29	0.043	0.060	0.064

7.2.5.2.32 Case 32

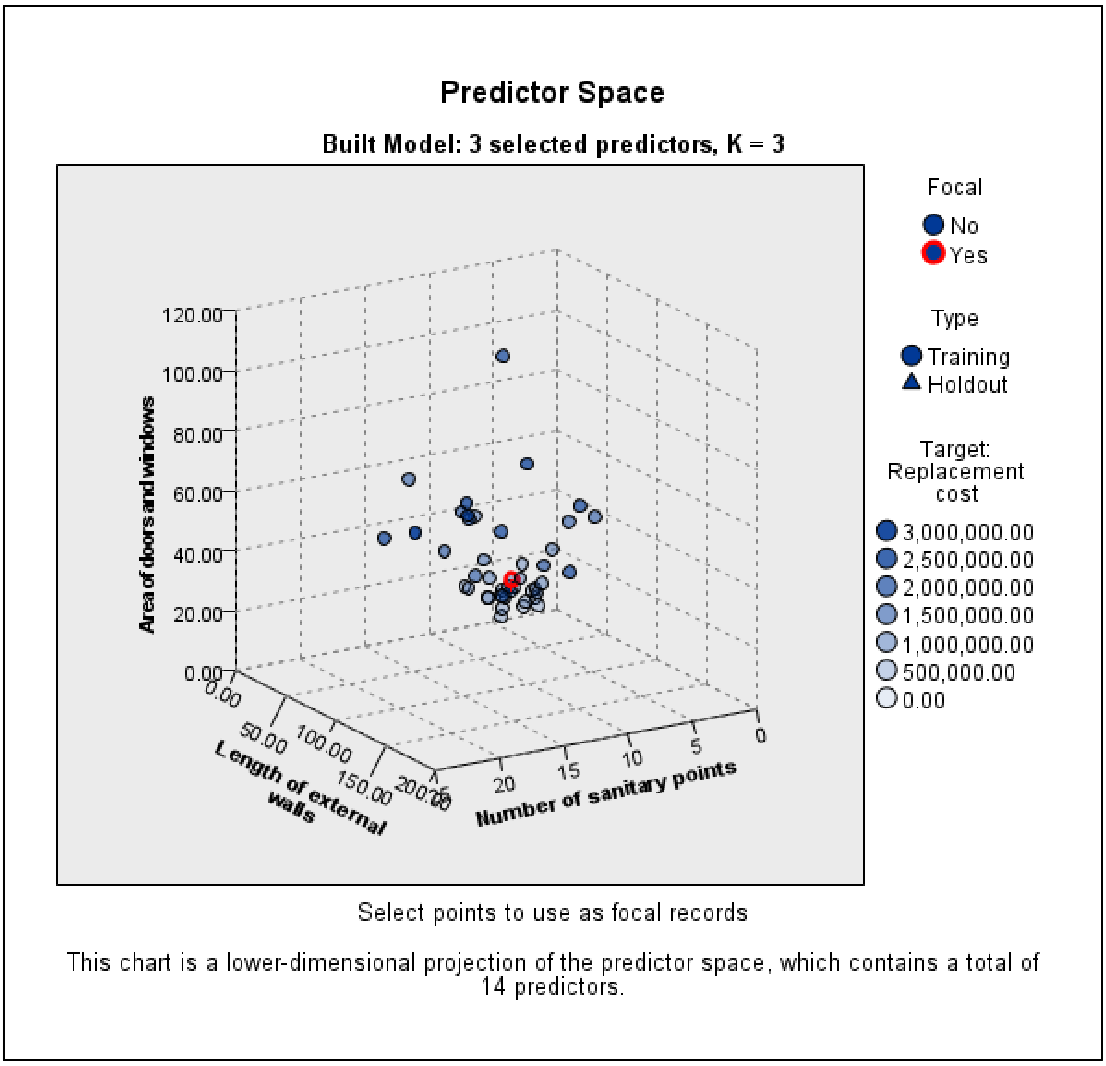

Figure 7.80: Predictor space for case 32 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.83: Nearest neighbours for case 32 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
32	31	42	30	0.191	0.198	0.199

7.2.5.2.33 Case 33

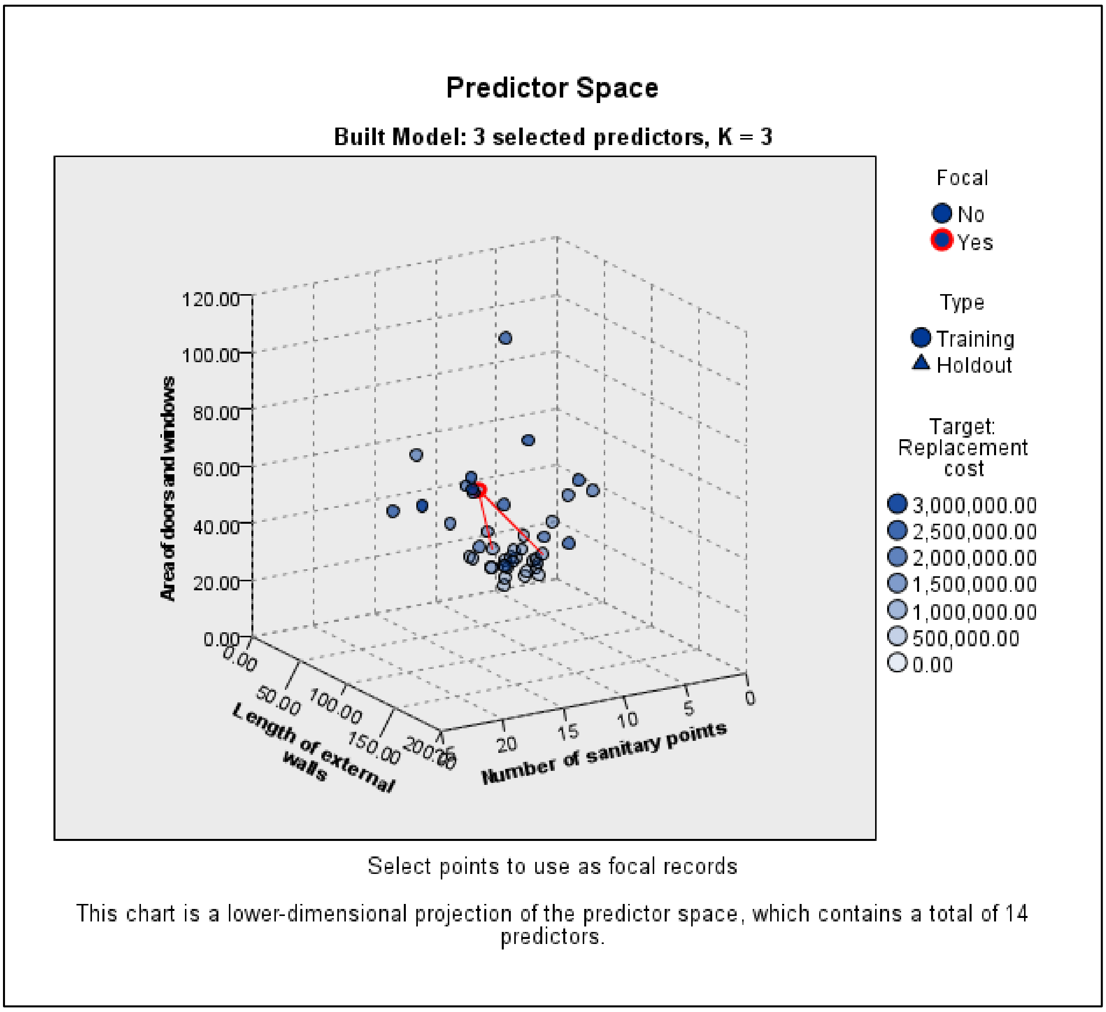

Figure 7.69: Predictor space for case 33 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.84: Nearest neighbours for case 33 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
33	18	17	35	0.330	0.397	0.485

7.2.5.2.34 Case 34

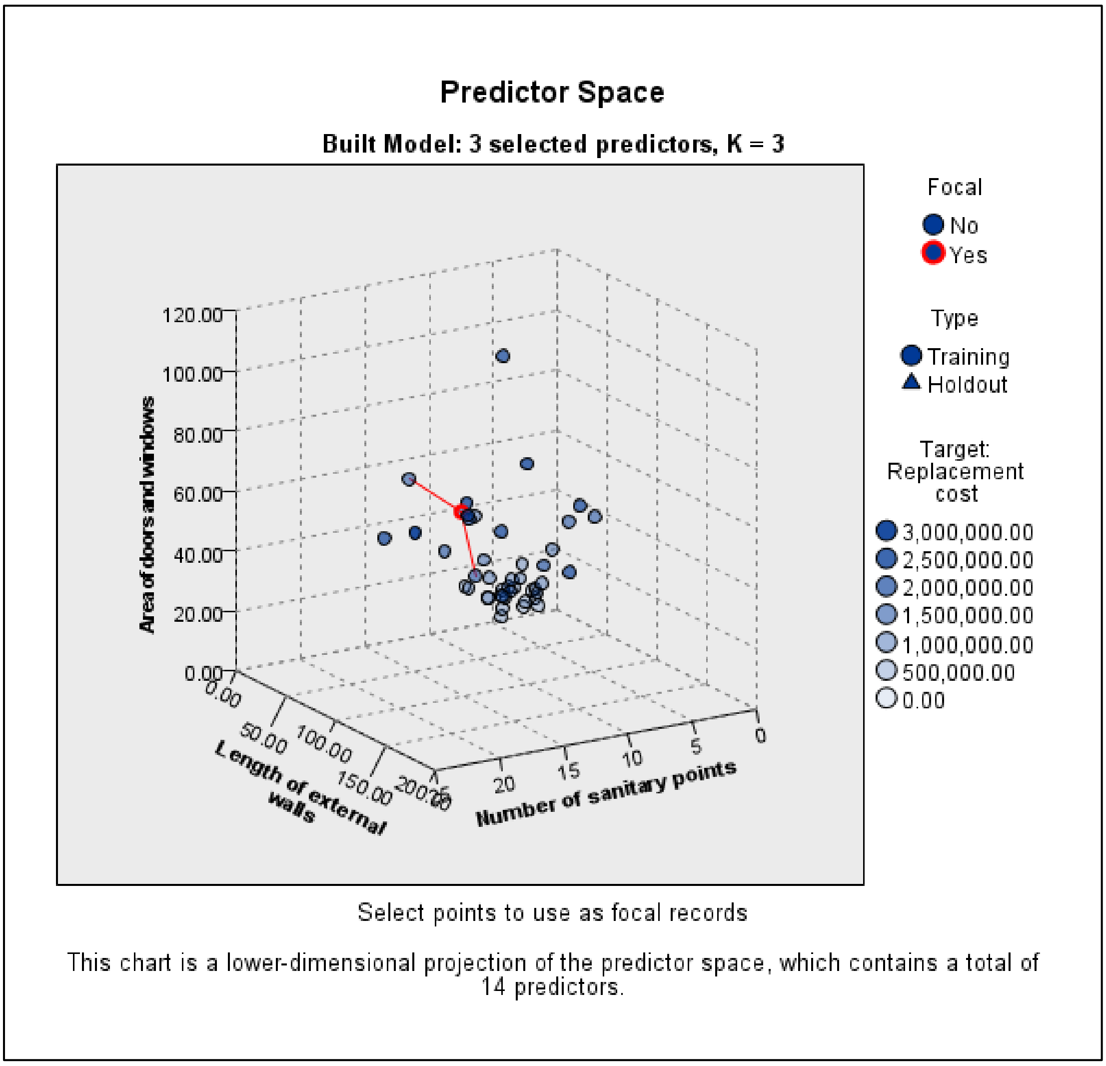

Figure 7.70: Predictor space for case 34 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.85: Nearest neighbours for case 34 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
34	7	21	39	0.239	0.309	0.325

7.2.5.2.35 Case 35

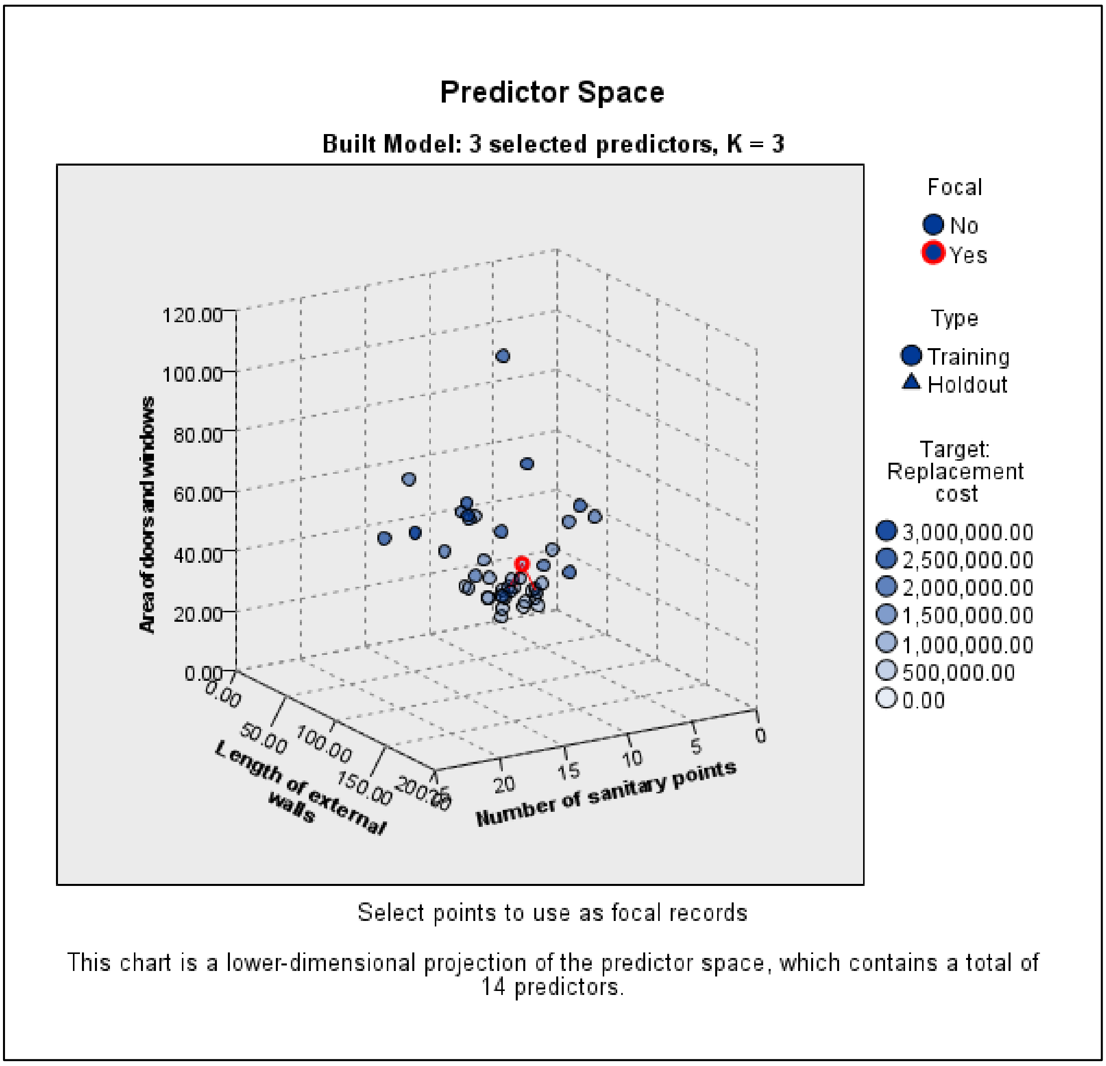

Figure 7.71: Predictor space for case 35 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.86: Nearest neighbours for case 35 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
35	36	31	24	0.102	0.154	0.163

7.2.5.2.36 Case 36

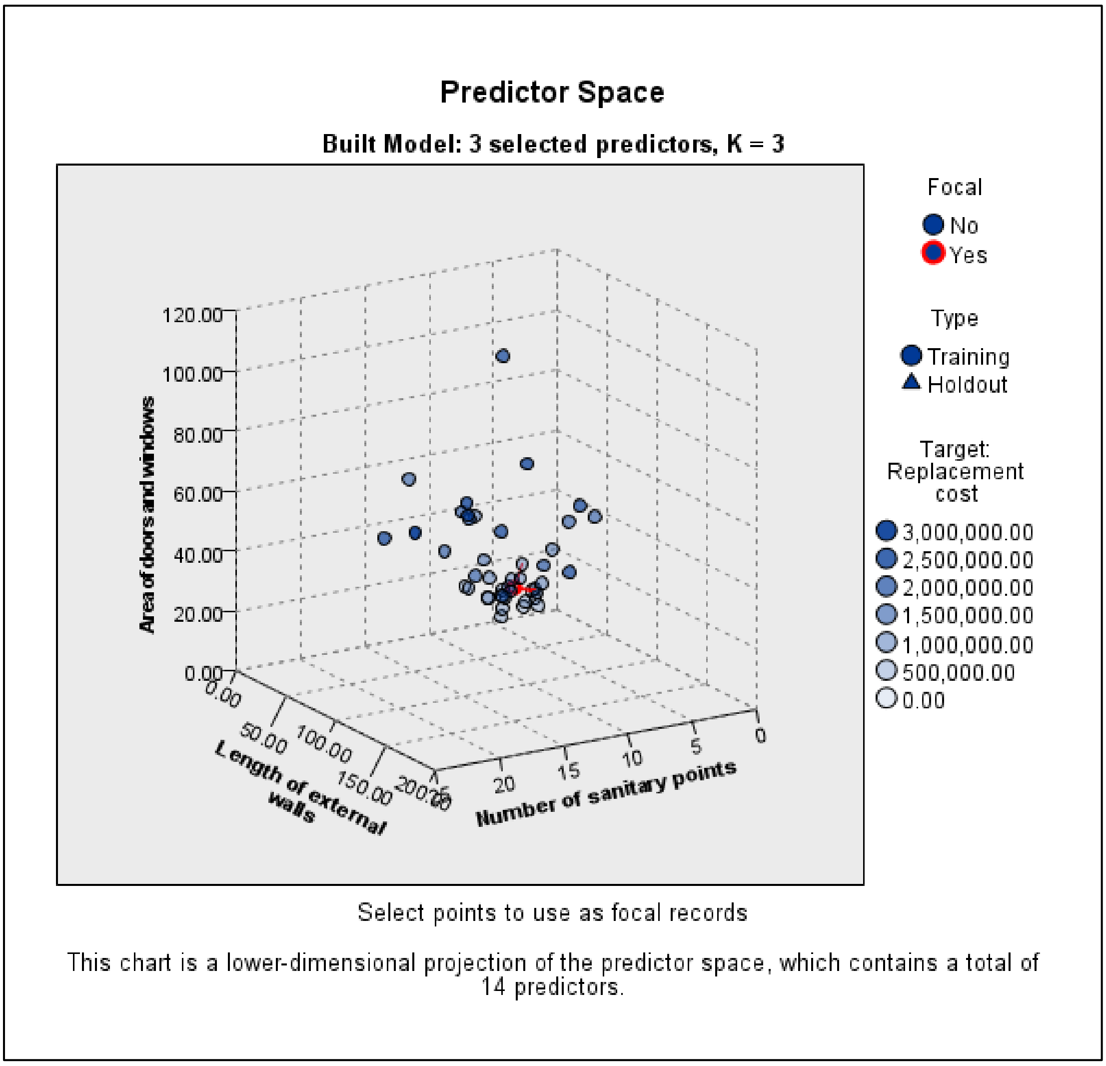

Figure 7.72: Predictor space for case 36 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.87: Nearest neighbours for case 36 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
36	35	24	23	0.102	0.106	0.121

7.2.5.2.37 Case 37

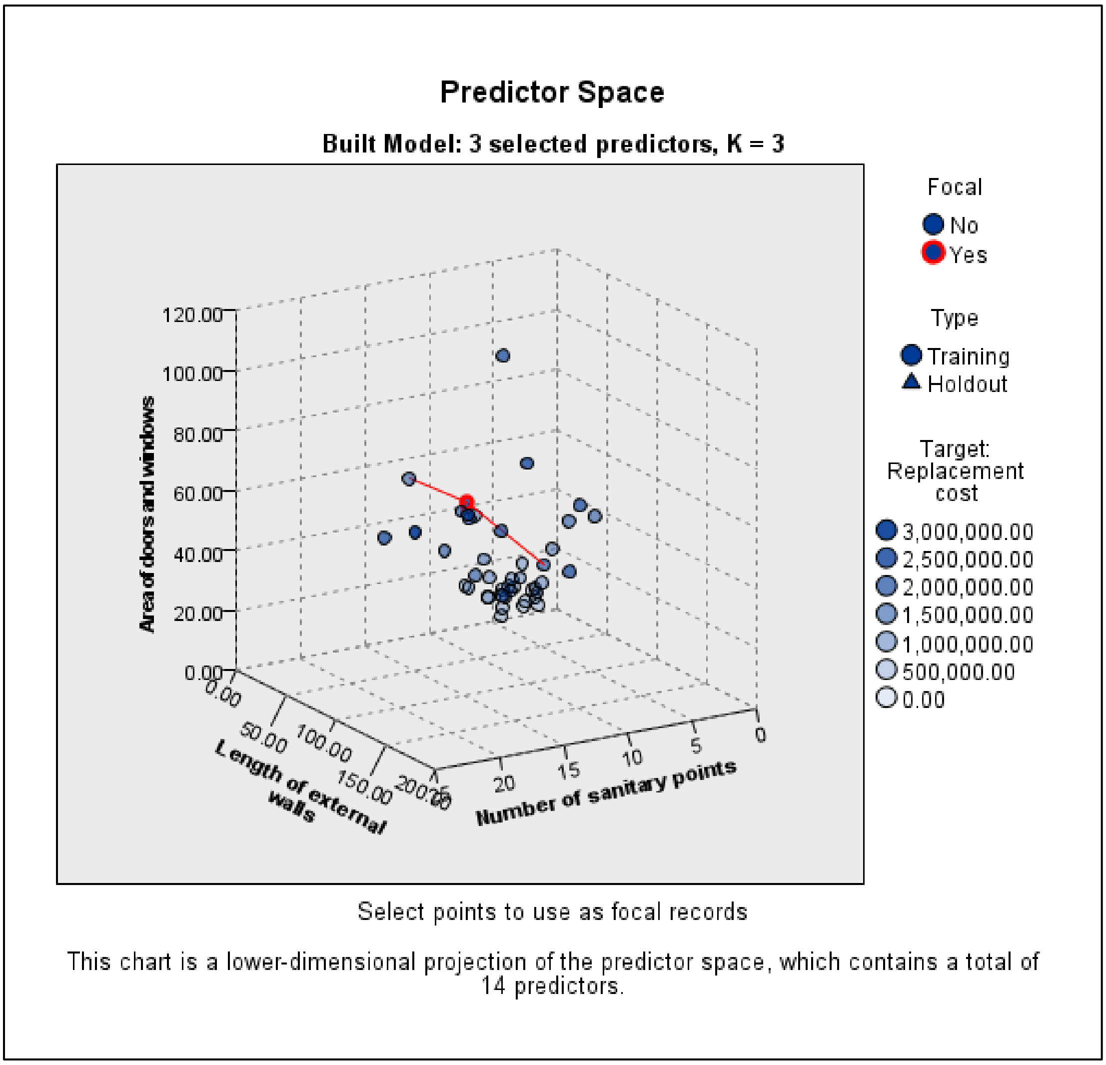

Figure 7.73: Predictor space for case 37 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.88: Nearest neighbours for case 37 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
37	20	34	7	0.450	0.466	0.487

7.2.5.2.38 Case 38

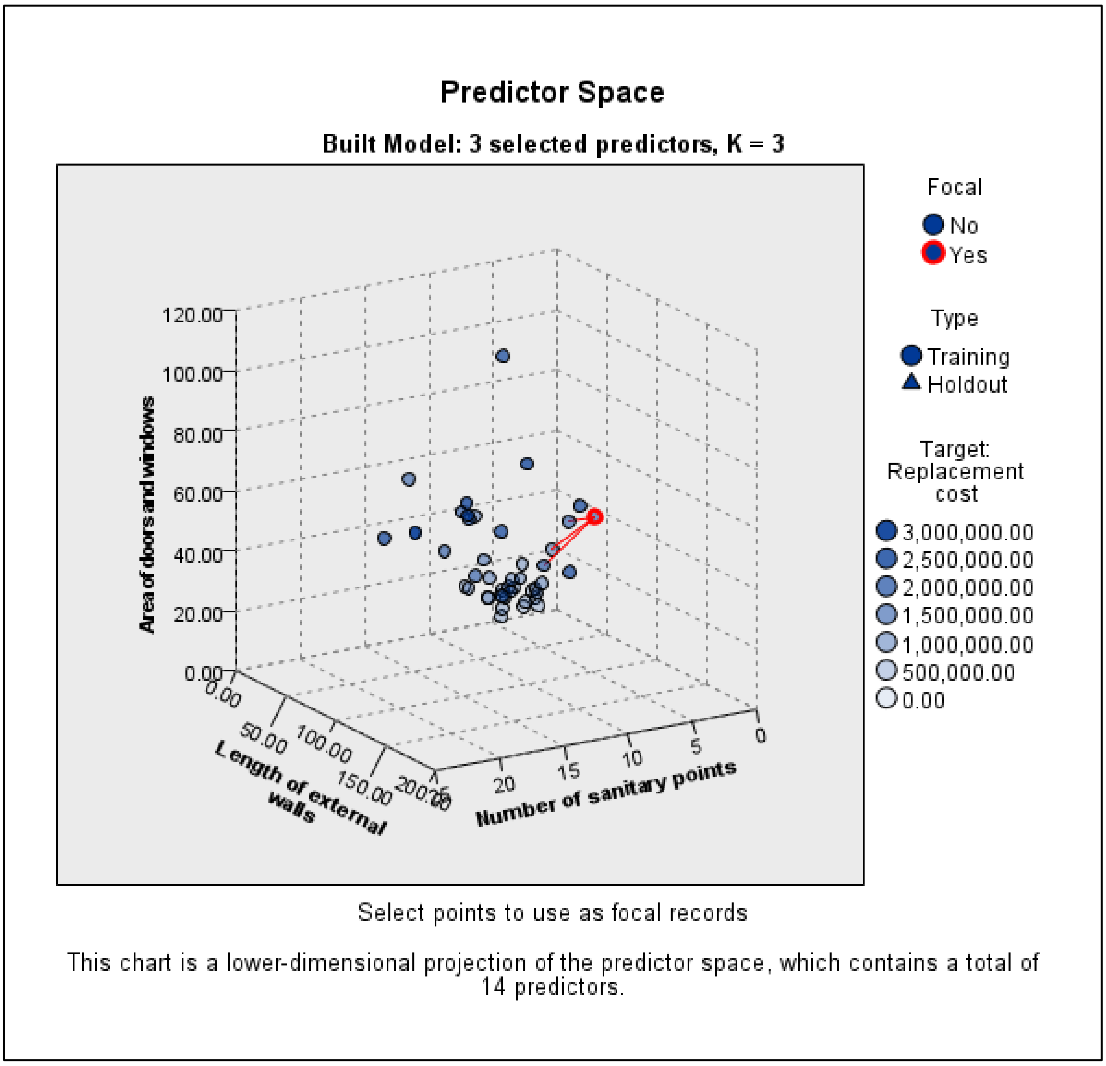

Figure 7.74: Predictor space for case 38 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.89: Nearest neighbours for case 38 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
38	45	27	28	0.057	0.089	0.100

7.2.5.2.39 Case 39

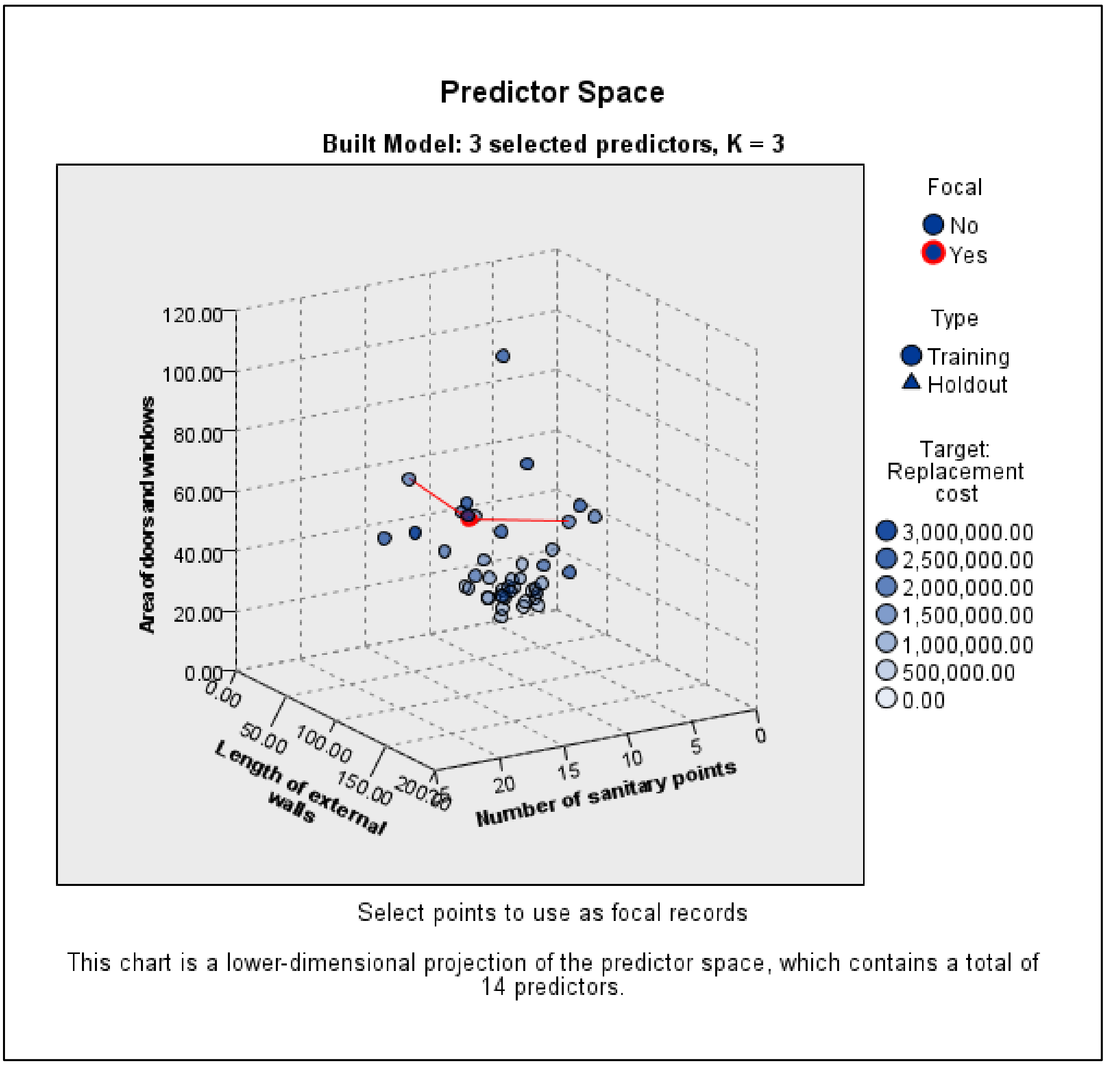

Figure 7.75: Predictor space for case 39 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.90: Nearest neighbours for case 39 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
39	34	10	7	0.325	0.343	0.354

7.2.5.2.40 Case 40

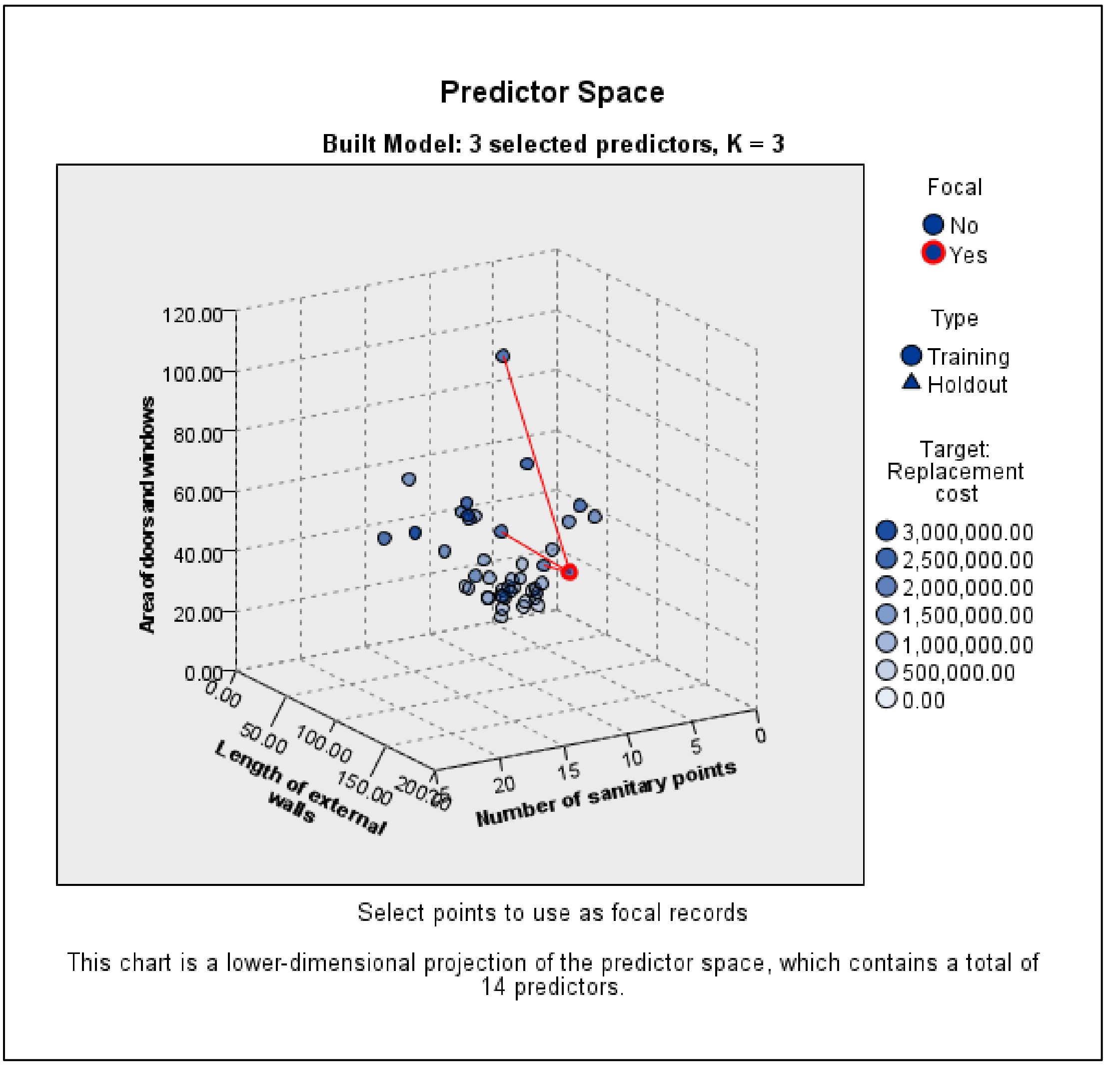

Figure 7.76: Predictor space for case 40 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.91: Nearest neighbours for case 40 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
40	19	20	13	0.732	0.757	0.772

7.2.5.2.41 Case 41

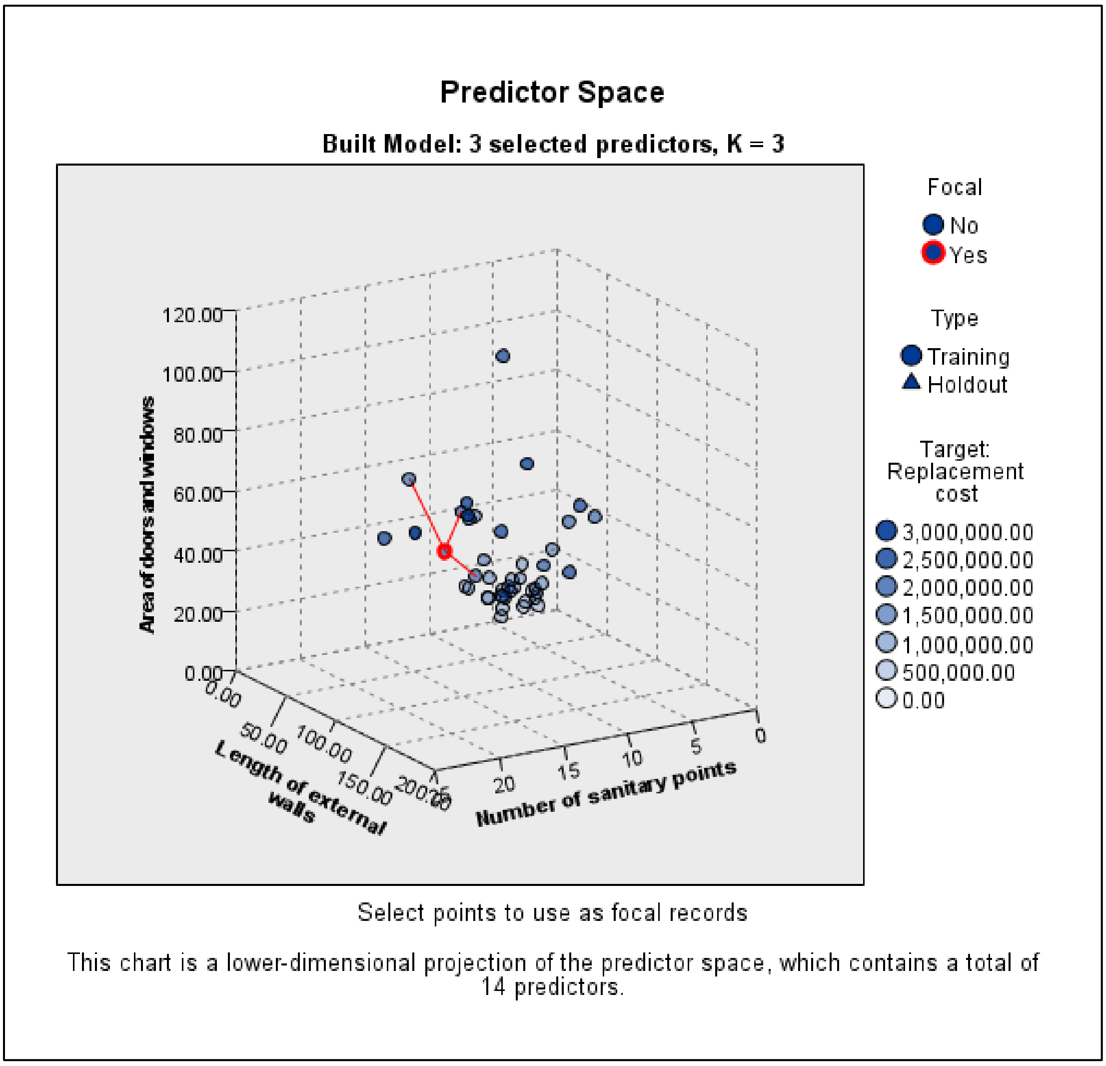

Figure 7.77: Predictor space for case 41 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.92: Nearest neighbours for case 41 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
41	34	21	7	0.345	0.411	0.421

7.2.5.2.42 Case 42

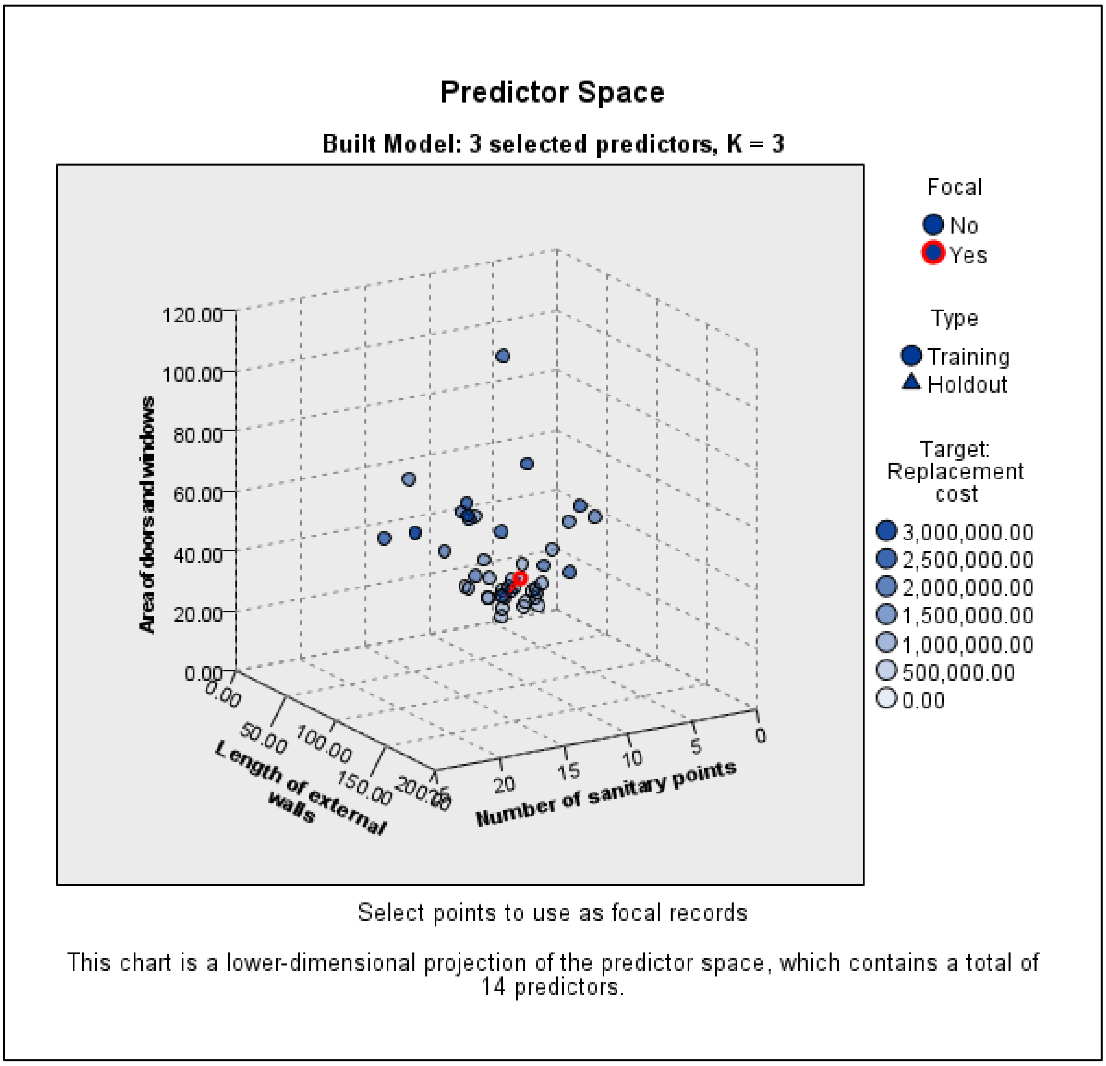

Figure 7.90: Predictor space for case 42 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.93: Nearest neighbours for case 42 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
42	30	31	29	0.153	0.166	0.175

7.2.5.2.43 Case 43

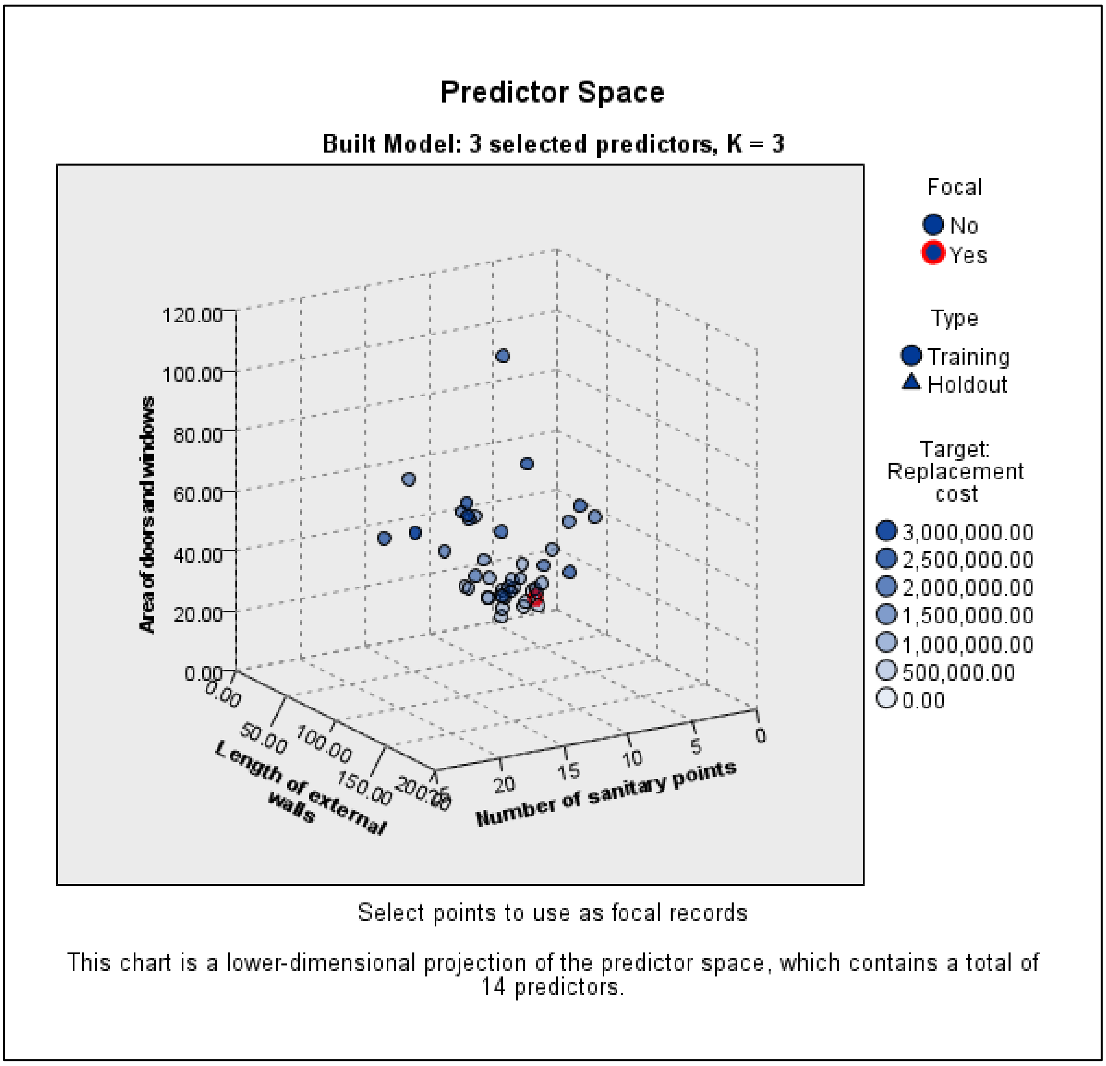

Figure 7.78: Predictor space for case 43 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.94: Nearest neighbours for case 43 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
43	23	24	44	0.090	0.094	0.122

7.2.5.2.44 Case 44

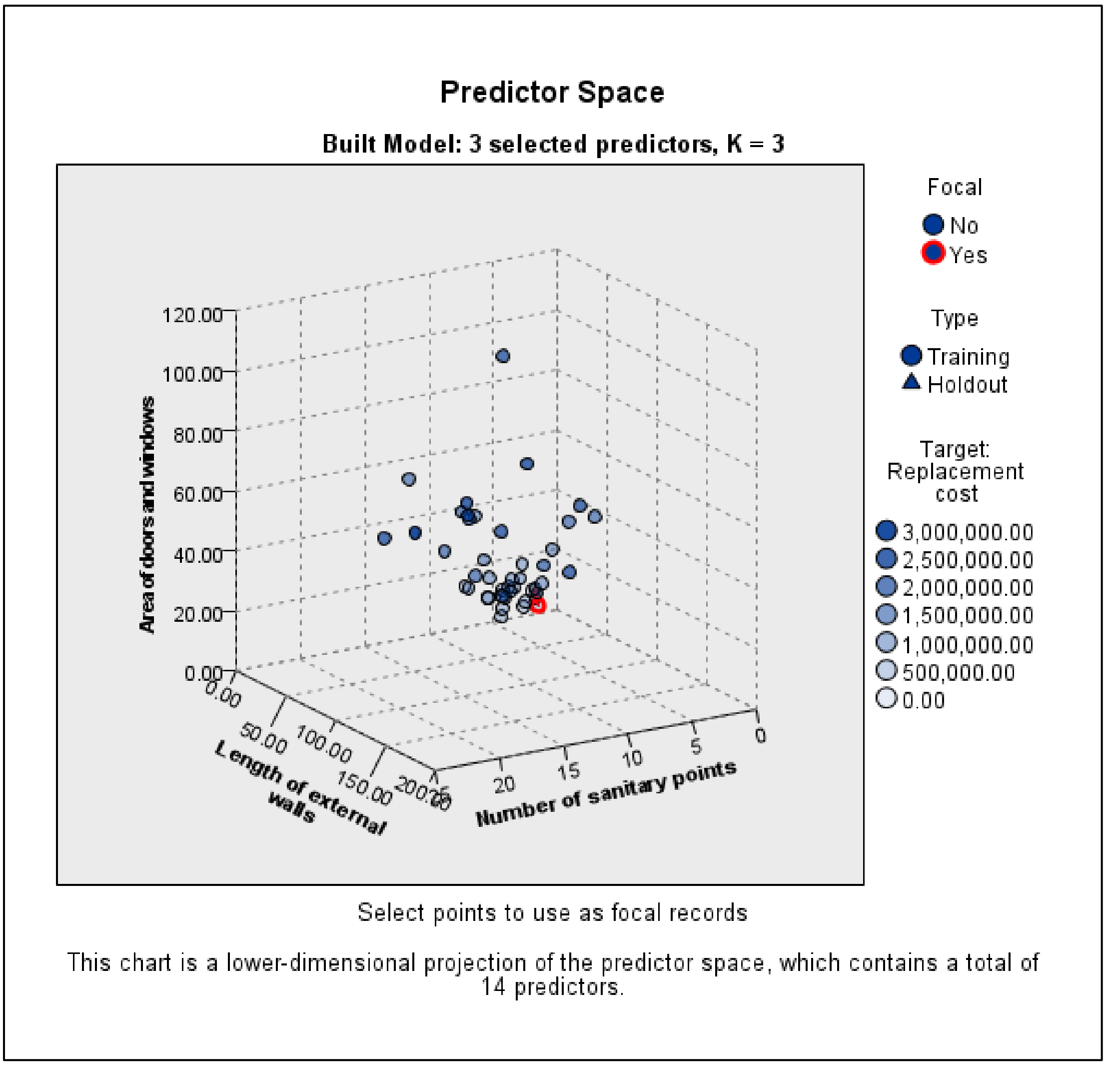

Figure 7.79: Predictor space for case 44 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.95: Nearest neighbours for case 44 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
44	43	24	23	0.122	0.133	0.136

7.2.5.2.45 Case 45

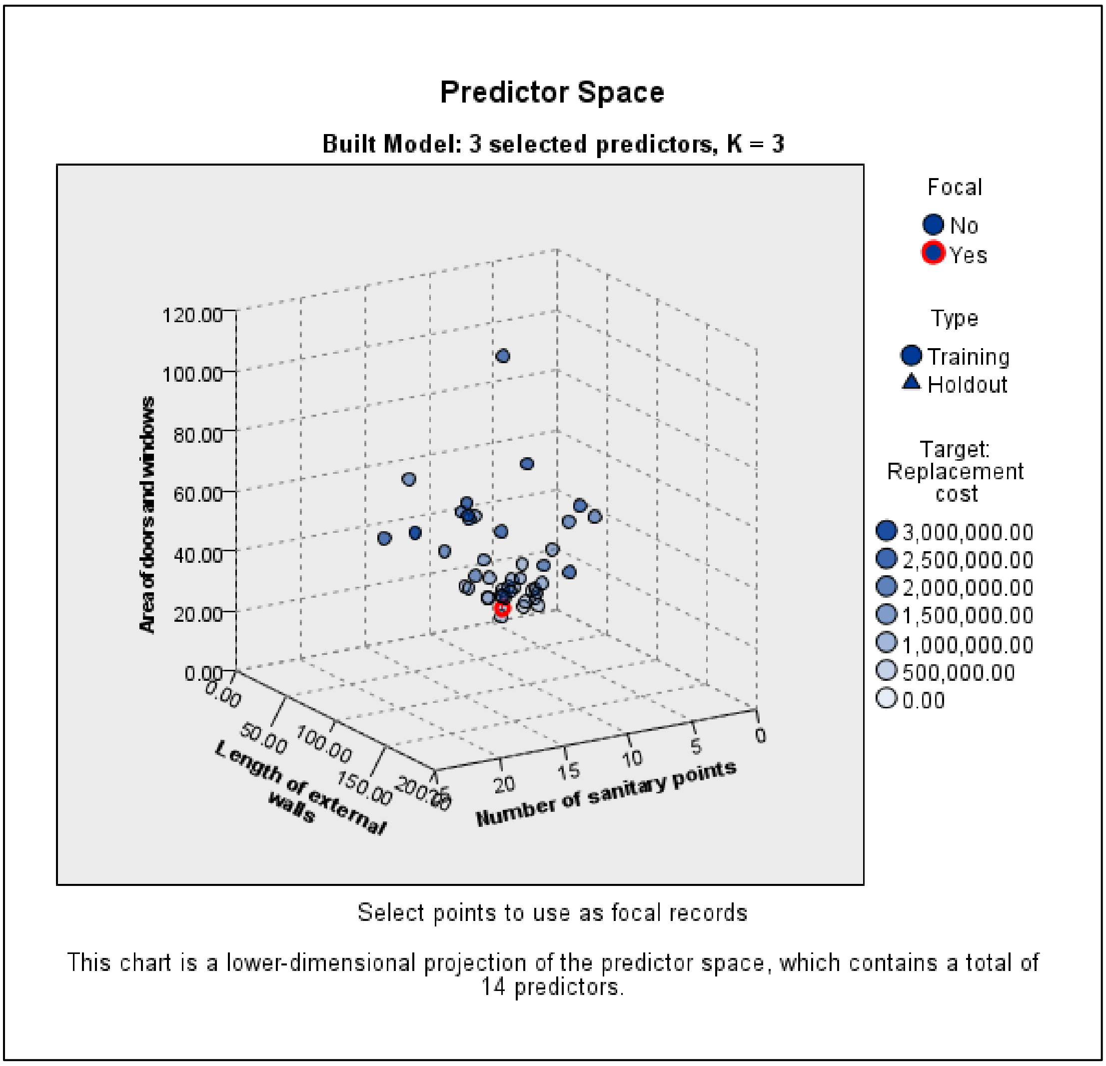

Figure 7.80: Predictor space for case 45 14-feature weighted (generated by IBM® SPSS® Statistics)

Table 7.96: Nearest neighbours for case 45 14-feature weighted (generated by IBM® SPSS® Statistics)

Focal Record	Nearest Neighbours			Nearest Distances		
	1	2	3	1	2	3
45	29	27	28	0.101	0.105	0.115

7.2.6 Comparison of the Nearest Neighbours and Euclidean distances for the two scenarios

The Nearest Neighbours are compared to determine how the selection of the neighbours differs for the two scenarios. The comparison of the Nearest Neighbours is set out in Table 7.97. The Euclidean distances are compared to see how near or how far the neighbours are in the different scenarios. The closer the neighbours are to the focal record, the more similar they are to the focal point. The comparison of the Euclidean distances is set out in Table 7.98.

Table 7.97: Comparison of the Nearest Neighbours for the two scenarios

Cases	14-Feature unweighted	14-Feature weighted
1	2, 3, 4	2, 3, 4
2	1, 3, 4	1, 3, 4
3	1, 2, 4	1, 2, 4
4	3, 5, 6	3, 5, 6
5	3, 4, 6	3, 4, 6
6	3, 4, 5	3, 4, 5
7	21, 34, 39	21, 34, 39
8	9, 32, 42	9, 32, 42
9	8, 30, 42	8, 17, 42
10	16, 20,39	16, 20, 39
11	14, 16, 34	16, 34, 38
12	11, 13, 16	11, 13, 16

13	11, 16, 19	11, 16, 19
14	8, 9, 42	8, 9, 42
15	12, 16, 22	12, 16, 22
16	11, 34, 39	11, 34, 39
17	28, 30, 31	28, 30, 31
18	17, 31, 33	17, 31, 33
19	12, 13, 20	12, 13, 16
20	10, 21, 34	10, 21, 34
21	7, 8, 34	7, 8, 34
22	15, 34, 41	15, 34, 41
23	24, 36, 43	24, 36, 43
24	23, 36, 43	23, 36, 43
25	26, 27, 28	26, 27, 28
26	25, 27, 28	25, 27, 28
27	28, 29, 31	28, 29, 31
28	27, 29, 31	27, 29, 31
29	28, 30, 31	28, 30, 31
30	28, 29, 31	28, 29, 31
31	27, 28, 29	27, 28, 29
32	30, 31, 42	30, 31, 42
33	17, 18, 35	17, 18, 35
34	7, 21, 39	7, 21, 39
35	24, 31, 36	24, 31, 36
36	23, 24, 35	23, 24, 35
37	7, 20, 34	7, 20, 34
38	27, 28, 45	27, 28, 45
39	7, 10, 34	7, 10, 34
40	13, 19, 20	13, 19, 20

41	7, 21, 34	7, 21, 34
42	29, 30, 31	29, 30, 31
43	23, 24, 44	23, 24, 44
44	23, 24, 43	23, 24, 43
45	27, 28, 29	27, 28, 29

Of the forty-five cases, the neighbours of only three, or 6,67% of cases, differed in the comparison between the 14-feature unweighted and weighted scenarios, and in each case, only one of the three neighbours differed. 93,3% of the cases were the same, indicating that the feature weightings had a minimal impact. The differing cases are 9, 11 and 19. All three of these cases are situated outside the densely populated areas.

Table 7.98: Comparison of the Euclidean distances for the two scenarios

Cases	14-Feature unweighted	14-Feature weighted
1	0.306, 0.454, 0.576	0.081, 0.123, 0.156
2	0.306, 0.327, 0.386	0.081, 0.090, 0.106
3	0.202, 0.327, 0.454	0.055, 0.090, 0.123
4	0.202, 0.330, 0.358	0.055, 0.090, 0.097
5	0.107, 0.330, 0.481	0.029, 0.090, 0.131
6	0.107, 0.358, 0.506	0.029, 0.097, 0.137
7	0.894, 1.062, 1.326	0.239, 0.287, 0.354
8	0.858, 1.010, 1.016	0.232, 0.269, 0.273
9	0.786, 1.016, 1.025	0.210, 0.273, 0.273
10	1.285, 1.285, 1.458	0.340, 0.343, 0.393
11	1.352, 1.689, 1.691	0.364, 0.451, 0.452

12	1.751, 1.916, 2.214	0.471, 0.515, 0.597
13	1.737, 1.855, 2.106	0.472, 0.496, 0.570
14	1.258, 1.269, 1.380	0.334, 0.338, 0.366
15	1.919, 2.238, 2.601	0.512, 0.598, 0.694
16	1.303, 1.352, 1.384	0.343, 0.364, 0.367
17	0.624. 0.671, 0.695	0.165, 0.177, 0.184
18	1.089, 1.227, 1.488	0.288, 0.330, 0.390
19	1.855, 2.229, 2.276	0.496, 0.598, 0.609
20	1.186, 1.262, 1.271	0.321, 0.337, 0.338
21	1.062, 1.083, 1.170	0.287, 0.290, 0.309
22	1.591, 1.919, 1.995	0.428, 0.512, 0.534
23	0.092, 0.343, 0.450	0.025, 0.090, 0.121
24	0.092, 0.358, 0.391	0.025, 0.094, 0.106
25	0.334, 0.370, 0.396	0.092, 0.101, 0.108
26	0.268, 0.332, 0.396	0.073, 0.090, 0.108
27	0.113, 0.223, 0.250	0.031, 0.060, 0.068
28	0.113, 0.159, 0.245	0.031, 0.043, 0.066
29	0.186, 0.237, 0.245	0.050, 0.064, 0.066
30	0.186, 0.249, 0.286	0.050, 0.067, 0.077
31	0.159, 0.223, 0.237	0.043, 0.060, 0.064
32	0.716, 0.744, 0.745	0.191, 0.198, 0.199
33	1.227, 1.512, 1.842	0.330, 0.397, 0.485
34	0.894, 1.170, 1.221	0.239, 0.309, 0.325
35	0.379, 0.584, 0.607	0.102, 0.154, 0.163
36	0.379, 0.391, 0.450	0.102, 0.106, 0.121
37	1.692, 1.763, 1.832	0.450, 0.466, 0.487
38	1.098, 1.159, 1.271	0.057, 0.089, 0.100
39	1.221, 1.285, 1.326	0.325, 0.343, 0.354

40	2.775, 2.828, 2.889	0.732, 0.757, 0.772
41	1.310, 1.557, 1.588	0.345, 0.411, 0.421
42	0.581, 0.629, 0.660	0.153, 0.166, 0.175
43	0.343, 0.358, 0.450	0.090, 0.094, 0.122
44	0.450, 0.496, 0.507	0.122, 0.133, 0.136
45	0.383, 0.397, 0.433	0.101, 0.105, 0.115

Comparing the unweighted and weighted scenarios for the 14-feature scenarios, it is apparent that the weighting of the features significantly influences the Euclidean distances. It would therefore, not be feasible to consider the unweighted scenario any further.

Apart from the Euclidean distance indicating the similarity of the focal record and the neighbours, it ranks the neighbours for inclusion in the subsequent steps of the CBR methodology. If there were many neighbours, it would be sensible to rank them and then use only the nearest neighbours in further steps. In this research, there are few neighbours; hence, all the neighbours are included in the subsequent steps.

7.3 RE-USING AND REVISING THE NEIGHBOURS

The re-use of cases can either be partly or wholly. The design of this research allows for each case to be re-used fully. Each case consists of the same elements and features. Therefore, only the extent of each element and feature differs from case to case.

7.3.1 Revising the Nearest Neighbours

7.3.1.1 Presentation of the Mathematical Revision Model

The mathematical model proposed for revising the cases is based on pro-rata adjustments for every feature relative to the element they apply to. The model is explained in detail in this section. Developing an algorithm to deal with the detailed calculations in the mathematical model would be desirable. Each feature's alignment to each element is illustrated in Table 7.99.

Table 7.99: Alignment of elements and features

	ELEMENTS	APPLICABLE FEATURES
1	Ground floor construction	Construction area, area of the structure
2	External elevation	Area of the external envelope, area of external doors and windows, length of external walls, number of corners in the external walls, wall heights
3	Roofs	Roof area on the slope, roof pitch
4	Internal divisions	Length of internal walls, number of rooms, number of bedrooms, wall heights
5	Furniture, fixtures and equipment	Length of the furniture, fixtures and equipment
6	Plumbing services	Number of sanitary fittings
7	Electrical and mechanical services	Construction area

As indicated in Table 6.2, most of the costs for each case are in ground floor construction, the external envelope and the roof. The ground floor construction cost make-up and the external envelope require further detail; therefore, the elemental costs are further proportioned. The ground floor construction cost is split into the costs for the foundation walls and floor construction, and the external envelope cost is split into the walls cost and the doors and windows cost. The costs are expressed as percentages that are used in the mathematical model. The proportions for all the cases are set out in Table 7.100.

Table 7.100: Proportions for ground floor construction and external envelope

	CONSTRUCTION AREA	STRUCTURE AREA	INTERNAL AREA	FOUNDATION WALL COST AS % OF GROUND FLOOR CONSTRUCTION	EXTERNAL ENVELOPE AREA	AREA OF DOORS AND WINDOWS	AREA OF WALLS	DOOR AND WINDOW COST AS % OF EXTERNAL ENVELOPE
1	51	9	42	70%	74	10	64	20%
2	60	10	50	72%	85	12	73	18%
3	65	10	55	67%	88	16	72	23%
4	70	10	60	63%	91	16	75	22%
5	72	11	61	67%	87	22	65	33%
6	84	12	72	57%	97	22	85	40%
7	240	23	217	41%	233	69	164	40%
8	186	23	163	54%	173	34	139	34%

9	145	24	121	53%	269	34	235	25%
10	285	35	250	47%	271	49	222	37%
11	344	46	298	50%	363	62	301	41%
12	379	64	315	43%	222	88	134	47%
13	373	35	338	38%	313	111	202	57%
14	204	30	174	43%	222	25	197	29%
15	610	50	560	30%	448	70	378	37%
16	360	41	319	32%	290	58	232	38%
17	117	15	102	44%	160	26	134	31%
18	152	16	136	47%	166	21	145	27%
19	293	48	245	49%	366	61	305	32%
20	283	35	248	49%	272	36	236	26%
21	208	25	183	44%	274	36	238	43%
22	341	39	302	44%	271	63	208	50%
23	40	7	33	50%	84	14	70	39%
24	50	8	42	46%	94	15	79	35%
25	57	9	48	49%	107	14	93	28%
26	60	10	50	49%	89	9	80	29%
27	65	10	55	45%	111	16	95	33%
28	70	11	59	49%	128	18	110	37%
29	80	12	68	42%	131	16	115	32%
30	90	12	78	43%	133	19	114	33%
31	95	12	83	44%	135	20	115	38%
32	100	13	87	45%	147	23	124	39%
33	132	18	114	44%	120	50	70	53%
34	268	29	239	47%	273	55	218	41%
35	102	13	89	48%	124	27	97	38%
36	76	10	66	39%	115	18	97	38%

37	444	24	420	31%	235	56	179	38%
38	65	10	55	49%	101	14	87	34%
39	205	27.	178	42%	232	54	178	71%
40	405	47	358	53%	615	53	562	28%
41	282	27	255	32%	249	45	204	54%
42	119	16	103	48%	157	25	132	36%
43	51	8	43	53%	85	12	73	36%
44	55	10	45	41%	95	10	85	34%
45	60	11	49	51%	104	12	92	36%

The mathematical model is based on the following notations:

NN - Nearest Neighbour

FR - Focal record (case being estimated)

R - Value of elements

E1 - Ground floor construction

E2 - External envelope

E3 - Roof

E4 - Internal divisions

E5 - Furniture, fixtures and equipment

E6 - Plumbing services

E7 - Electrical and mechanical services

F1 - Construction area

$F1_p$ - Proportion of foundation wall cost

F2 - Structure area

F3 - Roof area (on slope)

$F4$ - External envelope area

$F4_p$ - Proportion of door and window costs

$F5$ - Wall height

$F6$ - Door and window area

$F7$ - Length of external walls

$F8$ - Length of internal walls

$F9$ - Number of sanitary fittings

$F10$ - Length of furniture, fixtures and equipment

Revision for the ground floor construction element:

$$\text{Revision E1} = [R_{E1} \times \frac{FR(F1-F2)}{NN(F1-F2)} \times (1 - F1_{p)}] + [R_{E1} \times \frac{FR(F2)}{NN(F2)} \times F1_p]$$

where the first part of the formula deals with the internal area and the second part deals with the structure area

Revision for external elevation element :

$$\text{Revision E2} = [R_{E2} \times \frac{FR(F4-F6)}{NN(F4-F6)} \times (1 - F4_{p)}] + [R_{E2} \times \frac{FR(F6)}{NN(F6)} \times F4_p] + [R_{E2} \times \frac{1}{NN(F4)} \times (FR_{F5} - NN_{F5}) \times NN_{F7} \times (1 - F4_{p)})]$$

where the first part of the formula deals with the external envelope area, the second part deals with the doors and windows area, and the third part deals with the wall height incorporating the wall length.

Revision for the roof element:

Revision E3 = [R_{E3} x $\frac{FR(F3)}{NN(F3)}$] where the formula deals with the roof area on the slope.

Revision for the internal divisions element:

Revision E4 = [R_{E4} x $\frac{FR(F8)}{NN(F8)}$] + [R_{E4} x $\frac{1}{NN(F8)}$ x (FR_{F5} - NN_{F5}) x NN_{F8}]

where the first part of the formula deals with the internal division length and the second part with the wall height.

Revision for the furniture, fixtures and equipment element:

Revision E5 = [R_{E5} x $\frac{FR(F10)}{NN(F10)}$] where the formula deals with the length of the furniture, fixtures and equipment.

Revision for the sanitary services element:

Revision E6 = [R_{E6} x $\frac{FR(F9)}{NN(F9)}$] where the formula deals with the number of sanitary fittings.

Revision for the electrical and mechanical services element:

Revision E7 = [R_{E7} x $\frac{FR(F1)}{NN(F1)}$] where the formula deals with the extent of electrical and mechanical services relative to the construction area.

The complete mathematical model for revising a nearest neighbour is:

$[R_{E1} \times \frac{FR(F1-F2)}{NN(F1-F2)} \times (1 - F1_{p})] + [R_{E1} \times \frac{FR(F2)}{NN(F2)} \times F1_{p}] + [R_{E2} \times \frac{FR(F4-F6)}{NN(F4-F6)} \times (1 - F4_{p})] + [R_{E2} \times \frac{FR(F6)}{NN(F6)} \times F4_{p}] + [R_{E2} \times \frac{1}{NN(F4)} \times (FR_{F5} - NN_{F5}) \times NN_{F7} \times (1 - F4_{p}))] + [R_{E3} \times \frac{FR(F3)}{NN(F3)}] + [R_{E4} \times \frac{FR(F8)}{NN(F8)}] + [R_{E4} \times \frac{1}{NN(F8)} \times (FR_{F5} - NN_{F5}) \times NN_{F8}] + [R_{E5} \times \frac{FR(F10)}{NN(F10)}] + [R_{E6} \times \frac{FR(F9)}{NN(F9)}] + [R_{E7} \times \frac{FR(F1)}{NN(F1)}]$

This formula is applied to every nearest neighbour for every case in the 14-feature weighted scenario. The outcome for every nearest neighbour revision for the 14-feature scenario is set out in Table 7.101. This table displays the revised values for the focal records, which are the revised nearest neighbours; the actual values for the focal records, which are the measured and priced bills of quantities; the difference between the revised value and the actual value; and the difference expressed as a percentage. These percentages ultimately inform the retaining step of the CBR methodology. For example, the nearest neighbours to focal point 1 are 2, 3 and 4. Column A shows the focal point and its three nearest neighbours consecutively. Column B shows the focal record's revised value based on the nearest neighbour. Column C shows the actual value for the focal record being adjusted. Column D shows the difference between the actual value of the focal record and the adjusted value for the same focal record based on a specific nearest neighbour. The adjusted value is derived from applying the proposed complete mathematical model. The difference shown in Column D referred to as the error margin in the proposed estimation technique, is expressed as a percentage in Column E. These percentages ultimately inform the retaining step of the CBR methodology.

Table 7.101: Results for revision of Nearest Neighbours for the 14-Feature weighted scenario

Cases compared (A)	Revised values for focal record (B)	Actual value for focal record (C)	Difference or error (D)	% Error (E)
1 with 2	346 011	328 000	(18 011)	(5.49)
1 with 3	368 244	328 000	(40 244)	(12.26)
1 with 4	349 213	328 000	(21 213)	(6.47)
2 with 1	344 527	356 600	12 073	3.39
2 with 3	388 247	356 600	(31 647)	(8.87)
2 with 4	376 195	356 600	(19 595)	(5.49)
3 with 1	369 274	386 600	17 326	4.48
3 with 2	401 893	386 600	(15 293)	(3.96)
3 with 4	408 925	386 600	(22 325)	(5.77)
4 with 3	393 809	407 300	13 491	3.31
4 with 5	424 265	407 300	(16 965)	(4.17)
4 with 6	436 277	407 300	(28 977)	(7.11)
5 with 3	432 753	449 500	16 747	3.73
5 with 4	444 101	449 500	5 399	1.20
5 with 6	477 027	449 500	(27 527)	(6.12)
6 with 3	459 109	493 900	34 792	7.04
6 with 4	482 242	493 900	11 658	2.36
6 with 5	493 411	493 900	489	0.10
7 with 21	1 740 306	1 461 300	(279 006)	(19.09)
7 with 34	1 482 628	1 461 300	(21 328)	(1.46)
7 with 39	1 718 234	1 461 300	(256 934)	(17.58)

8 with 9	1 197 686	1 109 000	(88 686)	(8.00)
8 with 32	970 811	1 109 000	138 189	12.46
8 with 42	964 023	1 109 000	144 977	13.07
9 with 8	971 934	978 300	6 366	0.65
9 with 30	786 873	978 300	191 427	19.57
9 with 42	918 947	978 300	59 353	6.07
10 with 16	2 015 335	1 526 000	(489 335)	(32.07)
10 with 20	1 529 008	1 526 000	(3 008)	(0.20)
10 with 39	2 131 848	1 526 000	(605 848)	(39.70)
11 with 13	2 265 022	2 098 000	(167 022)	(7.96)
11 with 16	2 667 569	2 098 000	(569 569)	(27.15)
11 with 34	1 991 449	2 098 000	106 551	5.08
12 with 11	2 5137 712	2 312 500	(225 212)	(9.74)
12 with 13	2 340 452	2 312 500	(27 952)	(1.21)
12 with 16	2 388 418	2 312 500	(75 918)	(3.28)
13 with 11	2 149 398	2 102 300	(47 098)	(2.24)
13 with 16	2 201 237	2 102 300	(98 937)	(4.71)
13 with 19	2 201 934	2 102 300	(108 632)	(5.17)
14 with 8	1 183 181	1 259 000	75 819	6.02
14 with 9	1 245 712	1 259 000	13 288	1.06
14 with 42	952 382	1 259 000	306 618	24.35
15 with 12	3 243 803	2 796 500	(447 303)	(16.00)
15 with 16	3 451 529	2 796 500	(655 029)	(23.42)
15 with 22	3 186 257	2 796 500	(389 757)	(13.94)
16 with 11	2 246 675	2 268 500	21 825	0.96
16 with 34	1 812 238	2 268 500	456 262	20.11
16 with 39	2 394 435	2 268 500	(125 935)	(5.55)
17 with 28	671 408	880 200	208 792	23.72

17 with 30	736 570	880 200	143 630	16.32
17 with 31	721 323	880 200	158 877	18.05
18 with 17	991 478	877 000	(114 478)	(13.05)
18 with 31	756 658	877 000	120 342	13.72
18 with 33	1 162 059	877 000	(285 059)	(32.50)
19 with 12	2 214 275	2 127 600	(86 675)	(4.07)
19 with 13	2 148 696	2 127 600	(21 096)	(0.99)
19 with 16	2 224 142	2 127 600	(96 542)	(4.54)
20 with 10	1 608 225	1 722 000	113 775	6.61
20 with 21	1 908 241	1 722 000	(186 241)	(10.82)
20 with 34	1 809 249	1 722 000	(87 249)	(5.07)
21 with 7	1 468 231	1 603 000	134 769	8.41
21 with 8	1 115 334	1 603 000	487 666	30.42
21 with 34	1 577 800	1 603 000	25 200	1.57
22 with 15	2 084 600	2 138 000	53 400	2.50
22 with 34	1 784 611	2 138 000	353 389	16.53
22 with 41	1 996 539	2 138 000	141 461	6.62
23 with 24	346 569	324 600	(21 969)	(6.77)
23 with 36	484 541	324 600	(159 941)	(49.27)
23 with 43	345 820	324 600	(21 220)	(6.54)
24 with 23	353 555	371 700	18 145	4.88
24 with 36	517 205	371 700	(145 505)	(39.15)
24 with 43	386 048	371 700	(14 348)	(3.86)
25 with 26	407 147	435 400	28 253	6.49
25 with 27	505 749	435 400	(70 349)	(16.16)
25 with 28	458 850	435 400	(23 450)	(5.39)
26 with 25	499 061	452 800	(46 261)	(10.22)
26 with 27	492 022	452 800	(39 222)	(8.66)

26 with 28	484 953	452 800	(32 153)	(7.10)
27 with 28	529 402	514 000	(15 402)	(3.00)
27 with 29	491 046	514 000	22 954	4.47
27 with 31	541 318	514 000	(27 318)	(5.31)
28 with 27	524 415	535 700	11 285	2.11
28 with 29	508 221	535 700	27 479	5.13
28 with 31	565 651	535 700	(29 951)	(5.59)
29 with 28	568 877	545 300	(23 577)	(4.32)
29 with 30	665 911	545 300	(120 611)	(22.12)
29 with 31	587 644	545 300	(42 344)	(7.77)
30 with 28	596 212	651 900	55 688	8.54
30 with 29	552 617	651 900	99 283	15.23
30 with 31	630 456	651 900	21 444	3.29
31 with 27	580 671	612 200	31 529	5.15
31 with 28	615 734	612 200	(3.534)	(0.58)
31 with 29	572 558	612 200	39 642	6.48
32 with 30	867 061	751 700	(115 361)	(15.35)
32 with 31	591 655	751 700	160 045	21.29
32 with 42	813 257	751 700	(61 557)	(8.19)
33 with 17	1 076 000	972 000	(104 000)	(10.70)
33 with 18	867 145	972 000	104 855	10.79
33 with 35	849 510	972 000	122 490	12.60
34 with 7	1 527 469	1 600 000	72 531	4.53
34 with 21	1 906 323	1 600 000	(306 323)	(19.15)
34 with 39	1 955 216	1 600 000	(355 216)	(22.20)
35 with 24	542 494	674 900	132 406	19.62
35 with 31	659 768	674 900	15 132	2.24
35 with 36	637 489	674 900	37 411	5.54

36 with 23	451 328	548 900	97 572	17.78
36 with 24	463 203	548 900	85 697	15.61
36 with 35	634 659	548 900	(85 759)	(15.62)
37 with 7	2 094 125	2 323 700	229 575	9.88
37 with 20	2 209 595	2 323 700	114 105	4.91
37 with 34	2 267 057	2 323 700	56 643	2.44
38 with 27	496 132	464 800	(31 332)	(6.74)
38 with 28	573 583	464 800	(108 783)	(23.40)
38 with 45	444 457	464 800	20 343	4.38
39 with 7	1 627 158	1 814 000	186 842	10.30
39 with 10	1 446 583	1 814 000	367 417	20.25
39 with 34	1 657 626	1 814 000	156 374	8.62
40 with 13	2 756 660	2 081 700	(674 960)	(32.42)
40 with 19	2 876 332	2 081 700	(794 632)	(38.17)
40 with 20	2 310 649	2 081 700	(228 949)	(11.00)
41 with 7	1 508 495	1 587 300	78 805	4.96
41 with 21	2 371 711	1 587 300	(784 411)	(49.42)
41 with 34	1 574 021	1 587 300	13 279	0.84
42 with 29	648 589	737 700	89 111	12.08
42 with 30	687 686	737 700	50 014	6.78
42 with 31	723 915	737 700	13 785	1.87
43 with 23	332 592	363 000	30 408	8.38
43 with 24	533 195	363 000	(170 195)	(46.89)
43 with 44	301 299	363 000	61 701	17.00
44 with 23	380 646	348 400	(32 246)	(9.26)
44 with 24	425 859	348 400	(77 459)	(22.23)
44 with 43	409 343	348 400	(60 943)	(17.49)
45 with 27	491 467	462 500	(28 967)	(6.26)

45 with 28	566 006	462 500	(103 506)	(22.38)
45 with 29	454 181	462 500	8 319	1.80

7.3.2 Revision results for the 14-feature weighted scenario

The results can be viewed at an overall model level, at the focal record level or at an individual prediction level. A combination of AACE's cost estimate classification system for detailed take-offs and unit costs and Ashworth and Skitmore's (1983) pre-tender estimate accuracy ranging between -10 and +10 is adopted as an acceptable adoption criterion for this research.

The mean absolute percentage error (MAPE) is a commonly applied accuracy measure. Using MAPE at the model level renders a result of 11,47%. This result, compared to the adoption criterion, would rule the model as inaccurate and, therefore, unable to estimate acceptable replacement costs. The error percentages in Table 7.101 suggest that this is a harsh view and warrants a more detailed analysis.

Using MAPE at the focal record level reveals that of the 45 predictions, 12 (27%) are between 3 and 5,99%; 10 (22%) are between 6 and 9,99%. Thus, 22 (49%) predictions fall within the adoption criterion. Nine (20%) predictions are between 10 and 14,99%. These would still be regarded as reasonably accurate and related to a provisional bill of quantities accuracy. Ten (22%) predictions are between 15 and 19,99%. This accuracy can be equated to an elemental estimate level when performed as an estimate and not following the same technique as in this researc of the calculators currently applied in South Africa. These results are considerably more significant than those of the superficial model level.

There are one hundred and thirty-five prediction iterations at the individual prediction level, as contained in Table 7.101. Of these predictions, 20 (15%) are between 0 and 2,99%; 32 (24%) are between 3 and 5,99%; 28 (21%) are between 6 and 9,99%. There are 80 (59%) predictions below the 10% accuracy adoption level.

However, it is more critical to establish the reasons for the inaccuracy of 41% of the cases than to be satisfied with the 59% acceptable accuracy level. Of these predictions, 16 (12%) are between 10 and 14,99%; 16 (12%) are between 15 and 19,99%; and 23 (17,0%) are 20% and above. A comparison was performed to determine whether all the cases were selected as NNs. Case 37 was selected once only; 14, 15, 38, 40, 41 and 44 were each selected twice; 5, 6, 9, 10, 12, 18, 19, 22, 26, 32, 33 and 45 were each selected three times; 13 and 20 were selected four times; 11, 17, 21, 25, 30, 35 and 43 were selected five times; 1, 2, 4, 8, 23 and 39 were selected six times; 7, 24, 29, 36 and 42 were each selected seven times; 3 and 27 were selected eight times; 16, 28 and 31 were each selected ten times and 34 was selected 11 times. The prediction accuracy for cases with the highest frequency was analysed further. It was found that case 34 produced estimates below 10% accuracy for 7 out of 11 times. Case 28 succeeded 8 out of 10 times, 31 in 7 of 10, but 16 only succeeded 3 of 10. Case 3 succeeded 6 of 8 times, and 27 succeeded 7 of 8.

Another case that did not perform well is 39, with 1 out of 6. The details of this case show that the doors and windows cost represents 71% of the external envelope. The structure area ratio is much higher than in other cases because the internal walls are one brick, not half brick. It also has considerably more furniture than the other cases. The bad performance of this case indicates that the model is sensitive to the features and their multipliers (ratios to the cases being estimated). The closer the features' quantities for cases are to each other, the better the estimate.

7.4 RETAINING THE NEIGHBOURS

This research has not introduced new cases to the dataset to be retained but used the entire dataset as training data. The discussion of the prediction results in the previous section indicates the relative estimate accuracy success judged at the individual case level.

The dataset is relatively small, with some cases concentrated in some areas and others spread sparsely across the prediction space. The inaccurate results are influenced mainly by longer Euclidean distances used to retrieve the NNs. The Euclidean distances for cases 10, 11, 12, 13, 14, 15, 16, 22, 19, 37, 39, 40 and 41 in Table 7.98 are considerably longer than the other cases. Therefore, the revision ratios for these cases, relative to those being estimated, will be smaller, leading to less accurate estimates.

Instead of rejecting the cases that have not performed well and removing them from the dataset, the dataset should be extended to fill the spaces between the cases for more accurate estimating. Cases to be added to the dataset must be structured exactly as the existing cases.

7.5 SUMMARY

The CBR methodology proposed for conducting the empirical research consists of the four steps of retrieving, re-using, revising and retaining cases. The success of the method hinges on the accurate retrieval of cases. Therefore, the retrieval process is discussed in great detail. The kNN machine learning algorithm was chosen to perform the task. Two scenarios based on 14 unweighted features and 14 weighted features were developed to demonstrate the importance of feature weighting, the influence on the selection of the nearest neighbours and the importance of the number of neighbours to be chosen. Cross-validation was performed to verify the appropriate number of neighbours.

The cases were fully re-used and revised, implementing a mathematical model based on the features. Accuracy testing at the model and focal record levels showed the necessity to test the accuracy at an individual case level. One hundred and thirty-five predictions were performed. Based on the 14-feature scenario, the predictions were accurate to 10% in 59% of the cases. Although the model shows promise of success, it is apparent from the calculations that it is sensitive to the number of neighbours, feature weightings and adjustment ratios.

CHAPTER 8: CONCLUSION AND DIRECTION FOR FUTURE RESEARCH

8.1 INTRODUCTION

A perpetual under-insurance gap exists due to the application of inappropriate building cost models for insurance replacement costs of residential properties in South Africa. The dire consequences insureds suffer when damage occurs to their properties gave rise to this research.

This research endeavoured to address the main research question of whether a cost model to determine replacement costs of residential buildings for short-term insurance purposes in South Africa that is complex enough to deliver accurate estimates and yet simple enough to be understood, used and interpreted by homeowners could be developed.

The sub-questions that needed to be addressed to ensure that the main question was indeed answered are:

- How the elements for inclusion in the cost model should be defined.
- What factors (features) to enter into the cost model.
- Whether a satisfactory level of estimation accuracy can be obtained.

8.2 RESEARCH PROCESS

The research process entailed determining the size and trends of the residential property market in Chapter 1. The secondary data consulted revealed that the residential property market's size and development trends, informed by building plans passed and buildings completed, revealed that stand-alone houses between 30 and 80 m^2 represented 54,3% and houses larger than 80 m^2 represented 45,5% of the market.

Gaining an understanding of the nature, principles, classification, essentials, and trends of insurance was crucial for understanding what the outcome of the proposed cost model should be to satisfy the insurance requirements as set out in Chapter 3. The principle of indemnity and how it is entrenched in insurance contracts is paramount.

Reviewing the size of the South African insurance market, how it relates to global and peer insurance markets, how property insurance risk is perceived, and the importance and methods for determining the correct insurance values in Chapter 4 confirmed the need for increasing insurance cover.

The outline of how procurement is conducted in the built environment, what traditional building cost models exist, their accuracy levels, and the current cost models employed for insurance purposes globally, as set out in Chapter 5, emphasised the shortcomings in the South African insurance industry.

The data presented in Chapter 6 was purposely developed for application in the CBR methodology. Built environment practice entrenched measuring methods were employed in the data development, and great care was exercised to ensure the quality of the data.

8.3 RESEARCH FINDINGS

8.3.1 Elements used in the cost model

The notion of elemental estimating is well entrenched in built environment practice. The novelty for insurance purposes is that the elements are designed to address common damage patterns to buildings in events of fire, storms, and the like. Although the proposed cost model is designed to determine replacement costs to serve as sums insured in insurance contracts, it is envisaged that these elemental costs could also be employed in claims processes. The elements can, however, not deviate too far from their traditional composition, as that would detract from the purpose of arranging costs in elements so that the elemental costs for different designs can be compared directly.

The test for successfully defining the elements is entrenched in the cost revisions performed through the mathematical model, where the elemental costs were applied to the pro rata ratios of the features. The relative success achieved by applying the mathematical model is indicative of the elemental arrangement being fit for purpose.

8.3.2 Features used in the cost model

The features were designed to address the shortcomings of the superficial cost models commonly applied in South Africa. The weights were automatically allocated to the features introduced into the kNN classification application of the IBM® SPSS® Statistics software. The influence of the weighting on the Euclidean distance was demonstrated in Table 7.98. From the predictor importance as set out in Table 7.4, it can be seen that the features are weighted relatively equally varying between 0.0682 and 000711 across the fourteen features, thus indicating that none of the features should be eliminated due to their high importance. The weighting ensures that all features contribute fairly to the model.

8.3.3 A satisfactory level of estimation accuracy

Of the one hundred and thirty-five prediction iterations performed, 20 (15%) were between 0 and 2,99%; 32 (24%) were between 3 and 5,99%; 28 (21%) were between 6 and 9,99%. Fifty-two of the predictions comfortably exceeded the 10% accuracy adoption level and another 28 (21%) also fell within the accuracy adoption level derived from the secondary data. Thus, 80

(59%) of the iterations can be retrieved into the dataset to be employed as nearest neighbours for future predictions.

Of the 55 (41%) predictions that did not reach the 10% accuracy adoption level, 16 (12%) fell between 10 and 15% accuracy, which would still be better than results produced by the superficial method, 16 (12%) fell between 15 and 20% and 23 (17%) were 20% higher than the actual elemental estimates.

Thus, it is fair to conclude that the proposed cost model does determine more accurate replacement costs of residential buildings for short-term insurance purposes in South Africa. The complexity of the model is evident from the steps applied in the CBR method. The model's simplicity lies in the fourteen features required to run it. The main problem is thus solved.

8.4 LIMITATIONS

The limitations of this research included the sample size, the representativeness of the sample of cases, the reliability and validity of the data, and the data classification.

The cases included in the sample represent a large range of sizes, as set out in Tables 6.1 and 6.2. and were aligned as closely as possible to the property development trends observed. However, there is a need to keep populating the dataset to include many more diverse cases to be used to identify the most appropriate nearest neighbours.

The reliability and validity of the data were managed to the best of the researcher's ability. Should the model be further developed for commercial purposes, introducing other data producers to the system could influence its reliability and validity.

The model's success hinges on the appropriate data classification. The model has proved to be sensitive to selecting the number of neighbours and the predictor importance. Every attempt was made to validate the selection.

8.5 FUTURE RESEARCH

This research was a first attempt to introduce a machine-learning technique to building cost model prediction in South Africa for improving insurance coverage. It is based on a specific machine-learning algorithm that was chosen based on the secondary data from international studies. The research must be expanded to test other machine-learning algorithms under the same conditions set out in this research.

This research applies to the cost prediction of residential buildings for insurance purposes. The research should be expanded to other building types, such as industrial buildings, office buildings, schools, and the like.

Datasets should be developed for use in the public domain to serve as benchmarking tools for all built environment stakeholders. No datasets exist in the public domain in South Africa. The quality of early-stage cost advice can be significantly improved when benefiting from selecting truly similar projects from a dataset to inform the estimation of a specific project.

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APPENDICES

Appendix 1 Elemental Estimate for Case 7

Appendix 2 Turnitin

Appendix 3 Certificate of Editing

APPENDIX 1

Item No		Unit	Quantity	Rate	Amount
	BILL NO. 1				
	GROUNDFLOOR CONSTRUCTION				
	FOUNDATIONS				
1	Construction area	m2	240		**Not Priced**
	SITE CLEARANCE, ETC				
	Site clearance				
2	Digging up and removing rubbish, debris, vegetation, hedges, shrubs and trees not exceeding 200mm girth, bush, etc	m2	324	25.00	8,100.00
	EXCAVATIONS FOR TRENCHES, HOLES, ETC.				
	Excavation in earth not exceeding 2m deep including risk of collapse of excavations				
3	Trenches	m3	46	180.00	8,280.00
	Extra over trench and hole excavations in earth for excavation in				
4	Soft rock	m3	4	450.00	1,800.00
5	Hard rock	m3	10	850.00	8,500.00
	Risk of collapse of excavations				
6	Sides of trench and hole excavations not exceeding 1,5m deep	m2	150	15.00	2,250.00
	Keeping excavations free of water				
7	Keeping excavations free of all water other than subterranean water		Item		500.00
	FILLING, ETC.				
	Earth filling obtained from the excavations or prescribed stockpiles on site, compacted to 93% Mod AASHTO density				
8	Backfilling to trenches, holes, etc	m3	49	185.00	9,065.00
	Carried Forward			R	38,495.00
	Bill No. 1 GROUNDFLOOR CONSTRUCTION				

	Brought Forward			R	38,495.00
9	Under floors	m3	34	185.00	6,290.00
	Compaction of surfaces				
10	Compaction of ground surface under floors etc including scarifying for a depth of 150mm, breaking down oversize material, adding suitable material where necessary and compacting to 93% Mod AASHTO density	m2	200	25.00	5,000.00
	Carried Forward			R	49,785.00

Bill No. 1
GROUNDFLOOR CONSTRUCTION

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No.	Description	Unit	Qty	Rate	Amount
	Brought Forward			R	49,785.00
	SOIL POISONING				
	Soil insecticide				
11	Under floors etc including forming and poisoning shallow furrows against foundation walls etc, filling in furrows and ramming	m2	200	25.00	5,000.00
	REINFORCED CONCRETE CAST AGAINST EXCAVATED SURFACES				
	20MPa/19mm concrete				
12	Strip footings	m3	20	1,350.00	27,000.00
	BRICKWORK				
	Sizes in descriptions				
	Where sizes in descriptions are given in brick units, "one brick" shall represent the length and "half brick" the width of a brick				
	Hollow walls etc				
	Descriptions of hollow walls shall be deemed to include leaving every fifth perpend of the bottom course of the external skin open as a weep hole.				
	Brickwork of NFP bricks in class II mortar				
13	230 mm Brick walls	m2	63	420.00	26,460.00
	BRICKWORK SUNDRIES				
	Brickwork reinforcement				
14	150 mm Wide reinforcement built in horizontally	m	185	5.00	925.00
	FACE BRICKWORK				
	? face bricks pointed with recessed horizontal and vertical joints				
15	Extra over brickwork for face brickwork	m2	41	185.00	7,585.00
	CONCRETE, FORMWORK AND REINFORCEMENT				
	Carried Forward			R	116,755.00
	Bill No. 1 GROUNDFLOOR CONSTRUCTION				

	Brought Forward			R	116,755.00
	REINFORCED CONCRETE				
	Class 25MPa/19mm concrete				
16	Surface beds cast in panels on waterproofing	m3	20	1,350.00	27,000.00
	REINFORCEMENT				
	Fabric reinforcement				
17	Type 193 fabric reinforcement in concrete surface beds, etc.	m2	200	45.00	9,000.00
	WATERPROOFING				
	DAMP PROOFING OF WALLS AND FLOORS				
	One layer of 250 micron USB Green waterproof sheeting sealed at laps				
18	Under surface beds	m2	200	25.00	5,000.00
	FLOOR COVERINGS, PLASTIC LININGS, ETC				
	FLOOR COVERINGS				
	Carpets				
19	On floors	m2	1	250.00	250.00
	SCREEDS				
	Screeds on concrete				
20	30 mm Thick on floors and landings	m2	203	85.00	17,255.00
21	Average 50 mm thick on floors to falls and currents	m2	1	105.00	105.00
	FLOOR TILING				
	Floor tiles fixed with adhesive to plaster (plaster elsewhere) flush pointed with tinted jointing compound				
22	On floors and landings	m2	194	250.00	48,500.00
	Carried Forward			R	223,865.00
	Bill No. 1 GROUNDFLOOR CONSTRUCTION				

	Brought Forward			R	223,865.00
	<u>MOSAIC TILES? x ? x ?mm ? No ? un?glazed floor tiles fixed with adhesive to bedding (bedding elsewhere) and flush pointed with tinted waterproof jointing compound</u>				
23	On floors and landings	m2	1	1,100.00	1,100.00
	Carried to Summary			R	224,965.00
	Bill No. 1 GROUNDFLOOR CONSTRUCTION				

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Item No			Quantity	Rate	Amount
	BILL NO. 2				
	EXTERNAL ENVELOPE				
1	Area of external envelope	m2	233		**Not Priced**
2	Length of external walls	m	70		**Not Priced**
3	Area of windows and external doors	m2	69		**Not Priced**
	PRECAST CONCRETE				
	Precast concrete finished smooth on exposed surfaces including bedding, jointing and pointing				
4	Window sills	m	23	95.00	2,185.00
	SUPERSTRUCTURE				
	Brickwork of NFP bricks in class II mortar				
5	115 mm Brick walls in beamfilling	m2	13	210.00	2,730.00
6	230 mm Brick walls	m2	265	420.00	111,300.00
	BRICKWORK SUNDRIES				
	Brickwork reinforcement				
7	150 mm Wide reinforcement built in horizontally	m	779	5.00	3,895.00
	Standard prestressed fabricated lintels				
8	110 x 75 mm Lintels in lengths not exceeding 3 m	m	86	75.00	6,450.00
9	110 x 75mm Lintels in lengths exceeding 3m and not exceeding 4,5m(Provisional)	m	19	75.00	1,425.00
10	110 x 75mm Lintels in lengths exceeding 6 m and not exceeding 7,5 m	m	14	75.00	1,050.00
	Galvanized hoop iron cramps, ties, etc				
11	30 x 1,6mm Wall tie 500mm long with one end fixed to timber frame and other end built into brickwork	No	22	15.00	330.00
	Carried Forward			R	129,365.00
	Bill No. 2 EXTERNAL ENVELOPE				

	Brought Forward			R	129,365.00
12	30 x 1,6 mm Roof tie 1,75 m long with one end fixed to timber and other end built into brickwork	No	100	15.00	1,500.00
	NUTEC-CEMENT/FIBRE-CEMENT WINDOW SILLS				
	Natural grey sills in single lengths bedded in class I mortar including metal fixing lugs etc				
13	? x ?mm Wide sills set flat and slightly projecting	m	23	85.00	1,955.00
	DAMP PROOFING OF WALLS AND FLOORS				
	One layer of 375 micron "Consol Plastics Brikgrip DPC" embossed damp proof course				
14	In walls	m2	63	25.00	1,575.00
	DOORS, ETC				
	Wrought hardwood solid doors				
15	40 mm Door 813 x 2032 mm high	No	4	2,400.00	9,600.00
	Vinyl folding door including sliding track , lock and ironmongery				
16	Door 750 x 2100 mm high	No	1	1,500.00	1,500.00
	Wrought hardwood glazed doors including frame, glazing beads and brass ironmongery				
17	Sliding door 1800 x 2100 mm high	No	1	10,000.00	10,000.00
18	Sliding door 3050 x 2100 mm high	No	1	12,000.00	12,000.00
	FRAMED FRAMES, ARCHITRAVES, ETC				
	Wrought hardwood door frames				
19	1200 x 2100 mm Frame for door 815 x 2032mm high and side light 387 x 2032mm high (D2)	No	1	3,600.00	3,600.00
	WINDOWS				
	Wrought hardwood windows including glazing beads and brass ironmongery				
20	Window 6300 x 2000 mm high(G)	No	1	15,000.00	15,000.00
	Carried Forward			R	186,095.00
	Bill No. 2 EXTERNAL ENVELOPE				

	Brought Forward			R	186,095.00
	WALLS, ETC				
	Wrought ?				
21	Walling including frame	m2	14	350.00	4,900.00
	PRESSED STEEL DOOR FRAMES				
	1.2 mm Rebated frames suitable for one brick walls with one pair of brass butt hinges per door leaf				
22	Frame for door 813 x 2032 mm high	No	3	950.00	2,850.00
	STEEL WINDOWS, DOORS, ETC				
	Standard residential windows				
23	Window 1511 x 949 mm high (F)	No	2	975.00	1,950.00
24	Window 1022 x 949 mm high (E)	No	3	660.00	1,980.00
25	Window 2000 x 949 mm high (D)	No	1	1,300.00	1,300.00
26	Window 2000 x 1540 mm high (C)	No	5	2,100.00	10,500.00
27	Window 2400 x 1800 mm high (A)	No	2	2,950.00	5,900.00
	Cage type burglar screens, etc				
28	Burglar screen, 1711 x 1150 mm high (F)	No	2	1,675.00	3,350.00
29	Burglar screen, 1222 x 1150mm high (E)	No	3	1,200.00	3,600.00
30	Burglar screen, 2200 x 1150mm high (D)	No	1	2,150.00	2,150.00
31	Burglar screen, 2200 x 1740mm high (C)	No	5	3,250.00	16,250.00
32	Burglar screen, 2600 x 2000mm high (A)	No	2	4,450.00	8,900.00
	ALUMINIUM WINDOWS, DOORS, ETC				
	User Note:				
	A detail specification is to be inserted as necessary				
	Carried Forward			R	249,725.00
	Bill No. 2 EXTERNAL ENVELOPE				

	Brought Forward			R	249,725.00
	Note: Tenderers are referred to architect's drawings numbered 2782-012 annexed to these bills of quantities/accompanying these bills of quantities for tender purposes				
	<u>???Epoxy and polyester coated aluminium windows glazed with 6 mm safety glass and plugged to brickwork or concrete</u>				
33	Sliding door 2400 x 2100 mm high with lock, one pair of handles	No	1	10,000.00	10,000.00
34	Sliding door 2900 x 2100 mm high with lock, one pair of handles	No	1	12,000.00	12,000.00
	<u>INTERNAL PLASTER</u>				
	<u>One coat cement plaster on brickwork steel floated to receive paint</u>				
35	On walls	m2	76	65.00	4,940.00
36	On narrow widths	m2	17	70.00	1,190.00
	<u>EXTERNAL PLASTER</u>				
	<u>One coat plaster on brickwork</u>				
37	On walls	m2	248	65.00	16,120.00
38	On narrow widths	m2	13	70.00	910.00
	<u>GLAZING TO STEEL WITH PUTTY</u>				
	<u>4 mm Clear float glass</u>				
39	Panes exceeding 0,1m2 and not exceeding 0,5m2	m2	12	350.00	4,200.00
40	Panes exceeding 0,5m2 and not exceeding 2m2	m2	26	350.00	9,100.00
41	Panes exceeding 2m2 and not exceeding 4m2	m2	15	350.00	5,250.00
	<u>GLAZING TO WOOD WITH PUTTY</u>				
	<u>? mm Obscure glass</u>				
42	Panes exceeding 0,1m2 and not exceeding 0,5m2	m2	1	440.00	440.00
	Carried Forward			R	313,875.00
	Bill No. 2 EXTERNAL ENVELOPE				

	Brought Forward			R	313,875.00
	<u>ON FLOATED PLASTER</u>				
	<u>One coat primer and two coats interior quality PVA emulsion paint</u>				
43	On internal plastered walls	m2	546	60.00	32,760.00
	<u>One coat primer and two coats exterior quality PVA emulsion paint</u>				
44	On external plastered walls	m2	262	60.00	15,720.00
	<u>ON ROUGH CONCRETE</u>				
	<u>One coat primer and two coats exterior quality PVA emulsion paint</u>				
45	On window sills	m2	5	60.00	300.00
	<u>ON FIBRE CEMENT</u>				
	<u>Two coats super acrylic paint</u>				
46	On window sills	m2	5	65.00	325.00
	<u>ON METAL</u>				
	<u>One coat self-etching primer, one undercoat and two coats alkyd enamel paint on steel</u>				
47	On windows (both sides measured)	m2	63	65.00	4,095.00
48	On gates, grilles, burglar screens, balustrades, etc (both sides measured over the full flat area)	m2	80	65.00	5,200.00
49	On solid metal gates(both sides measured over the full flat area)	m2		65.00	**Not Priced**
50	On door frames	m2	5	65.00	325.00
	<u>ON WOOD</u>				
	<u>Two coats wood primer</u>				
51	On backs of frames, linings, etc not exceeding 300mm wide	m	141	25.00	3,525.00
	Carried Forward			R	376,125.00

Bill No. 2
EXTERNAL ENVELOPE

	Brought Forward			R	376,125.00
	<u>Two coats clear varnish</u>				
52	On timber walls	m2	28	65.00	1,820.00
53	On doors	m2	14	65.00	910.00
54	On glazed sliding door and frames	m2	20	65.00	1,300.00
55	On door frames	m2	3	65.00	195.00
56	On windows, sash doors and fanlights	m2	25	65.00	1,625.00
57	On skirtings, rails,cornices, etc not exceeding 300 mm girth	m	63	25.00	1,575.00
	Carried to Summary			R	383,550.00
	Bill No. 2 EXTERNAL ENVELOPE				

Item No			Quantity	Rate	Amount
	<u>BILL NO. 3</u>				
	<u>ROOF</u>				
	<u>ROOF COVERINGS</u>				
1	Area of roof covering on slope	m2	296	185.00	54,760.00
2	Ridges, valleys, etc	m	50	95.00	4,750.00
3	Area of roof covering on flat	m2	277		**Not Priced**
4	Area of roof covering on flat (without overhang)	m2	232		**Not Priced**
	<u>CARPENTRY AND JOINERY</u>				
	<u>Plate nailed trusses</u>				
5	Supply and installation of plate nailed roof construction over the entire building according to attached drawings (measured over flat) (including plate nailed trusses,bracing,purlins, wall plates, accessories, etc)	m2	262	350.00	91,700.00
	<u>CEILINGS, PARTITIONS AND ACCESS FLOORING</u>				
	<u>NAILED UP CEILINGS</u>				
	<u>6.4 mm "Rhino" gypsum plasterboard with taped and skimmed joints</u>				
6	????Ceilings including 38 x 38mm SA Pine brandering at 430mm centres	m2		185.00	**Not Priced**
7	Extra over ceiling for ? x ?mm trap door of ? x ?mm wrought softwood rebated framing with one ? x ?mm sawn softwood cross brander covered with ceiling board and fitted flush in opening	No		850.00	**Not Priced**
	<u>"Rhino" gypsum plasterboard cornices</u>				
8	75mm Coved cornices	m		45.00	**Not Priced**
9	????Ceilings including 38 x 38mm SA Pine brandering at 430mm centres	m2	218	185.00	40,330.00
	Carried Forward			R	191,540.00
	Bill No. 3 ROOF				

	Brought Forward			R	191,540.00
10	Extra over ceiling for ? x ?mm trap door of ? x ?mm wrought softwood rebated framing with one ? x ?mm sawn softwood cross brander covered with ceiling board and fitted flush in opening	No	1	850.00	850.00
	"Rhino" gypsum plasterboard cornices				
11	75mm Coved cornices	m	233	45.00	10,485.00
	RAINWATER DISPOSAL				
	?mm Galvanised sheet iron				
12	75 x 100 mm Eaves gutters	m	50	85.00	4,250.00
13	Extra over 75 x 100 mm eaves gutter for stopped end	No	8	20.00	160.00
14	Extra over 75 x 100 mm eaves gutter for angle	No	4	20.00	80.00
15	Extra over 75 x 100 mm eaves gutter for outlet for 75 mm diameter pipe	No	8	20.00	160.00
16	75 mm Diameter rainwater pipes	m	22	70.00	1,540.00
17	Extra over 75 mm diameter rainwater pipe for shoe	No	8	20.00	160.00
	ON METAL				
	One coat self-etching primer, one undercoat and two coats alkyd enamel paint on steel				
18	On eaves gutters not exceeding 300 mm girth	m	50	25.00	1,250.00
19	On downpipes not exceeding 300 mm girth	m	22	25.00	550.00
	Carried to Summary			R	211,025.00
	Bill No. 3 ROOF				

Item No			Quantity	Rate	Amount
	BILL NO. 4				
	INTERNAL DIVISIONS				
1	Length of internal dividsions	m	59		**Not Priced**
	MASONRY				
	SUPERSTRUCTURE				
	Brickwork of NFP bricks in class II mortar				
2	115 mm Brick walls	m2	135	210.00	28,350.00
3	230 mm Brick walls	m2	29	420.00	12,180.00
	BRICKWORK SUNDRIES				
	Brickwork reinforcement				
4	75 mm Wide reinforcement built in horizontally	m	397	3.00	1,191.00
5	150 mm Wide reinforcement built in horizontally	m	85	5.00	425.00
	SKIRTINGS				
	Wrought meranti				
6	19 x 75 mm Skirting	m	47	60.00	2,820.00
	DOORS, ETC				
	Semi-solid flush doors with veneer hung to steel frames				
7	40 mm Door 813 x 2032 mm high (D2)	No	6	850.00	5,100.00
	IRONMONGERY				
	LOCKS AND HANDLES				
	Lockset fitted to doors				
8	Lockset with striking plate, etc. (PC amount for the supply and deliver to site only: R150.00 per set)	No	6	245.00	1,470.00
	Carried Forward			R	51,536.00
	Bill No. 4 INTERNAL DIVISIONS				

	Brought Forward			R	51,536.00
	<u>SUNDRIES</u>				
9	Standard door stop plugged	No	6	55.00	330.00
	<u>PRESSED STEEL DOOR FRAMES</u>				
	<u>1.2 mm Rebated frames suitable for half brick walls with one pair of brass butt hinges per door leaf</u>				
10	Frame for door 813 x 2032 mm high	No	6	850.00	5,100.00
	<u>PLASTERING</u>				
	<u>INTERNAL PLASTER</u>				
	<u>One coat cement plaster on brickwork wood floated to receive tiles</u>				
11	On walls	m2	57	65.00	3,705.00
12	On narrow widths	m2	2	70.00	140.00
	<u>One coat cement plaster on brickwork steel floated to receive paint</u>				
13	On walls	m2	331	65.00	21,515.00
14	On narrow widths	m2	21	70.00	1,470.00
	<u>WALL TILING</u>				
	<u>Wall tiles (PC amount of R120/m2) fixed with adhesive to plaster (plaster elsewhere) flush pointed with tinted jointing compound</u>				
15	On walls	m2	57	250.00	14,250.00
16	On narrow widths	m2	1	280.00	280.00
	<u>PAINT WORK, ETC, TO NEW WORK</u>				
	<u>ON FLOATED PLASTER</u>				
	<u>One coat primer and two coats interior quality PVA emulsion paint</u>				
17	On internal plastered walls	m2	346	60.00	20,760.00
	Carried Forward			R	119,086.00
	Bill No. 4 INTERNAL DIVISIONS				

	Brought Forward			R	119,086.00
	ON METAL				
18	On door frames	m2	7	65.00	455.00
	ON WOOD				
	Two coats clear varnish				
19	On doors	m2	35	65.00	2,275.00
20	On skirtings, rails,cornices, etc not exceeding 300 mm girth	m	60	25.00	1,500.00
	Carried to Summary			R	123,316.00
	Bill No. 4 INTERNAL DIVISIONS				

Item No			Quantity	Rate	Amount
	BILL NO. 5				
	SERVICE PLUMBING				
1	No of points	No	17		**Not Priced**
2	Total for plumbing	No	1	92,950.00	92,950.00
	RAINWATER DISPOSAL				
	?mm Galvanised sheet iron				
3	75 x 100 mm Eaves gutters	m	-50	85.00	-4,250.00
4	Extra over 75 x 100 mm eaves gutter for stopped end	No	-8	20.00	-160.00
5	Extra over 75 x 100 mm eaves gutter for angle	No	-4	20.00	-80.00
6	Extra over 75 x 100 mm eaves gutter for outlet for 75 mm diameter pipe	No	-8	20.00	-160.00
7	75 mm Diameter rainwater pipes	m	-22	70.00	-1,540.00
8	Extra over 75 mm diameter rainwater pipe for shoe	No	-8	20.00	-160.00
	Carried to Summary			R	86,600.00
	Bill No. 5 SERVICES (PLUMBING)				

Item No		Unit	Quantity	Rate	Amount
	BILL NO. 6				
	SERVICES (ELECTRICAL)				
	ELECTRICAL INSTALLATION				
1	Electrical installation including light fittings, municipal connections, etc. (R)(building area approximately 605 m2)	m2	240	300.00	72,000.00
2	Allow for profit		Item		3,500.00
3	Allow for attendance		Item		3,500.00
	STOVE				
4	Stove and hob-supply and installation(R 10 000)(1 in No)		Item		10,000.00
5	Allow for profit		Item		500.00
6	Allow for attendance		Item		250.00
	Carried to Summary			R	89,750.00
	Bill No. 6 SERVICES (ELECTRICAL)				

Item No			Quantity	Rate	Amount
	BILL NO. 7				
	FURNITURE, FIXTURES AND EQUIPMENT				
	KITCHEN CUPBOARDS				
1	Kitchen cupboards supply and installation(R) (Approximately 20 m in length on plan)	m	20	5,500.00	110,000.00
2	Allow for profit		Item		5,500.00
3	Allow for attendance		Item		2,750.00
	CUPBOARD SHELVING, ETC				
4	Cupboards shelving, etc. supply and installation (Approximately 10 m in length on plan)(R37 500,00)	m	10	3,200.00	32,000.00
5	Allow for profit		Item		1,600.00
6	Allow for attendance		Item		800.00
	VANITY SLABS AND BATHROOM CUPBOARDS				
7	Vanity slabs and shelving etc. supply and installation (R) (Approximately 4 m in length on plan)	m	4	3,500.00	14,000.00
8	Allow for profit		Item		700.00
9	Allow for attendance		Item		350.00
	BATHROOM FITTINGS				
10	Bathroom fittings(toilet rolls,soap dishes etc) (supply and fit) (R)	No	14	950.00	13,300.00
	SHOWER DOORS				
11	Glass shower doors supply and installation(R 12 000) (2 in No)	No	1	4,500.00	4,500.00
12	Allow for profit		Item		**Not Priced**
13	Allow for attendance		Item		**Not Priced**
	Carried to Summary			R	185,500.00
	Bill No. 7 FURNITURE, FIXTURES AND EQUIPMENT				

Item No		Quantity	Rate	Amount
	BILL NO. 8			
	PRELIMINARIES			
1	Allowance for Preliminaries	Item		156,594.00
	Carried to Summary		R	156,594.00
	Bill No. 8 PRELIMINARIES			

Bill No	FINAL SUMMARY	Page No		Amount
1	GROUNDFLOOR CONSTRUCTION	5		224,965.00
2	EXTERNAL ENVELOPE	11		383,550.00
3	ROOF	13		211,025.00
4	INTERNAL DIVISIONS	16		123,316.00
5	SERVICES (PLUMBING)	17		86,600.00
6	SERVICES (ELECTRICAL)	18		89,750.00
7	FURNITURE, FIXTURES AND EQUIPMENT	19		185,500.00
8	PRELIMINARIES	20		156,594.00
	SUBTOTAL		R	1,461,300.00
	Carried to Form of Tender		R	1,461,300.00

APPENDIX 2

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1. CHAPTER 1: INTRODUCTION, BACKGROUND AND PROBLEM STATEMENTS

1.1 INTRODUCTION

Being or becoming a home-owner has significant benefits such as the creation of personal wealth, greater residential stability and security, better quality housing and living environment, social and physical benefits of interacting in a better neighbourhood and a sense of accomplishment derived from the social status and better control over one's own living conditions (Rohe and Lindblad, 2013). According to McCarthy *et al.* (2001), housing is an excellent financial investment that delivers a decent return and falls between the higher returns of riskier stock market investments and lower returns of less risky bond investments.

Any financial investment is associated with a fair amount of risk. For many individuals, the investment in a home is the most significant in their lives; hence, protecting the assets against any threats is paramount. In a 1958 song by Ollie Jones, Perry Como sings about love that makes the world go around and in the musical 'Cabaret' Lisa Minelli sings about money that makes the world go around. Still, according to Longcore (2006), insurance makes the world go around in a modern and sophisticated economic environment.

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