

South African Actuarial Journal

Volume 23



ACTUARIAL SOCIETY
OF SOUTH AFRICA

The *South African Actuarial Journal* is published by:
Actuarial Society of South Africa
PO Box 4464, Cape Town, 8000, South Africa
Website: www.actuarialsociety.org.za
Tel: +27 (0)87 073 8940

Editor: Conrad Beyers
Department of Actuarial Science
University of Pretoria
Private Bag X20, Hatfield, 0028, South Africa
Tel: +27 (0)12 420 3488
Email: saaj@actuarialsociety.org.za

Editorial Advisory Panel:
Anthony Asher (Australia)
Howard Bolnick (USA)
David Bowie (UK)
Barry Childs (South Africa)
Rob Dorrington (South Africa)
Angus Macdonald (UK)
Tjaart Esterhuysen, President of the Actuarial Society of South Africa

ISSN-8: 1680-2179
ISSN-13: 977-1680-2170-02



Actuarial Society of South Africa 2023

Content on this site is licensed under a Creative Commons Attribution 4.0 Licence.
For details see: <http://creativecommons.org/licenses/by/4.0>

The views and opinions of this journal are, unless otherwise stated, those of the authors. Editorial opinion or comment is, unless otherwise stated, that of the Editor and publication thereof does not indicate the agreement of the Actuarial Society of South Africa.

Contents

Refereed Papers

C SIRIRAM AND R HARRIS Applications of advanced analytics in healthcare	1
RD RUSCONI, FJC BEYERS AND NM WALTERS The contribution of insurers to systemic risk: A practical framework for regulators	23
T WESSELS AND JJ DE KLERK Technical experts as managers and servant leaders	59
GA WHITTAKER, K NAIDOO AND M LAWRENCE Towards the development of a three-state Markov chain model of working life expectancy in South Africa	103
Cumulative index	155

Applications of advanced analytics in healthcare

By C Siriram and R Harris

Submission date 6 January 2023

Acceptance date 11 September 2023

ABSTRACT

Analytics is increasingly becoming a key tool to support informed management decisions in organisations. An organisation's capability to make use of data analytics can enhance efficiencies and increase competitive differentiation and advantage. In the context of healthcare, analytics can support improved health outcomes and hence stakeholder value that enhances affordability and access to care. A deep understanding of analytics applications and techniques lends itself to identification of opportunities where analytics techniques are best applied. This paper introduces analytics maturity models as a tool to inform proportionally appropriate analytics applications. In this paper, a broader perspective is provided through consideration of the position on the analytics maturity curve of current techniques utilised in the healthcare system. The relationship between analytics maturity and analytics techniques in the healthcare space is then explored to demonstrate that there are opportunities for applying more sophisticated techniques to more advanced applications and hence enhance the efficiency of healthcare outcomes and health risk management

KEYWORDS

Healthcare, advanced analytics, health economics, South Africa, Africa

CONTACT DETAILS

Chantel Siriram, School of Statistics and Actuarial Science, University of the Witwatersrand, Johannesburg; Cell 082 578 1261; Email: crsiriram@gmail.com

Roseanne Harris, School of Statistics and Actuarial Science, University of the Witwatersrand
Tel: +27(11)716 6273; Email: roseanne.harris@wits.ac.za

1. INTRODUCTION

1.1 Analytics is increasingly being used as a tool to support informed management decision-making (Ghasemaghaei et al., 2018). Terms such as ‘advanced analytics’, ‘machine learning’ and ‘artificial intelligence’ tend to be used interchangeably to describe the use of large datasets to support decision-making (Watson, 2017). The distinction between analytics applications and analytics techniques utilised is often not well understood in industry (Watson, 2017). This paper aims to clarify the difference between analytics applications (the problem statement) and analytics techniques (the methodology used to determine a result). A deep understanding of analytics applications and techniques lends itself to identification of optimal instances where these techniques are best applied.

1.2 Effective use of analytics is important in the healthcare industry which is characterised by large volumes of data in the case of health insurance applications and the need to extrapolate sampling results in the case of health research applications (Barton & Court, 2012).

1.3 Maturity models are used to evaluate the extent to which business decisions are made making use of analytics techniques and the relative associated complexity thereof (Król & Zdonek, 2020).

1.4 In Section 2, analytics applications will be discussed in the context of various maturity models. The similarities and differences between these maturity models will be explored. Section 3 discusses various advanced analytics techniques and reviews the evolution of advanced analytics towards data driven decision-making in organisations which are on the mature end of the analytics maturity continuum.

1.5 Section 4 highlights the application of analytics in the healthcare industry in order to assess the current manner in which analytics techniques are used to inform strategic decision-making in healthcare. Analytics examples found in healthcare are categorised into the maturity framework and analytics techniques set out in Sections 2 and 3 to potentially identify areas in healthcare where analytics adoption can be improved.

2. ANALYTICS APPLICATIONS: MATURITY MODELS

2.1 Organisations utilise data to various extents to inform decision-making geared towards increasing competitive advantage or operational efficiencies (Król & Zdonek, 2020). An organisation’s capability to make use of data analytics can be defined by the degree of the organisation’s analytics maturity (ibid.).

2.2 Competitive advantage is best defined as an organisation’s ability to implement its strategy through the organisational vision, appropriate use of resources and capabilities, realising innovation and quality in products and services or manufacturing at lower production costs than competitors (Hameed, 2019). Porter (1989) states: “competitive advantage grows fundamentally out of value a firm is able to create for its buyers that exceeds the firm’s cost

of creating it. Value is what buyers are willing to pay, and superior value stems from offering lower prices than competitors for equivalent benefits or providing unique benefits that more than offset a higher price.”

2.3 In the healthcare context specifically, increased operational efficiencies will result in improved quality of care to a patient in the healthcare system (Yoon et al., 2016).

2.4 Analytics maturity can therefore be defined as the placement on an analytics continuum describing the extent to which an organisation acts on data (Król & Zdonek, 2020). Król & Zdonek (2020) and Menezes et al. (2019) categorise analytics maturity into five categories:

- **Descriptive analytics** – understanding the observed history through pattern identification: What happened?
- **Diagnostic analytics** – detection of relationships (correlations) between variables: Why did it happen?
- **Predictive analytics** – forecasting future expected scenarios: What may happen in future?
- **Prescriptive analytics** – modelling and simulation to suggest actions to be taken in order to make better decisions: What actions should be taken?
- **Cognitive analytics** – monitoring the relationship between action taken and outcome in real time to inform future optimal actions.

2.5 Król & Zdonek (2020) note further that in practice analytics maturity categories co-exist and complement each other. For this reason, analytics maturity is assessed considering a continuum. Menezes et al. (2019) support this approach stating there are often overlapping areas in the use of analytics in business. Shmueli & Koppius (2011) suggest that explanatory (descriptive and diagnostic) versus predictive (predictive, prescriptive and cognitive) approaches address two distinct goals i.e. analysing versus forecasting. Cao & Duan (2017) utilise eight categories to describe analytics: reporting, statistical analysis, alerting, forecasting, predictive modelling, optimisation, prescriptive analytics and actionable knowledge delivery. Reporting, statistical analysis, alerting and forecasting are grouped together as explicit analytics (which aligns to descriptive and diagnostic analytics in paragraph 2.4); predictive modelling, optimisation, prescriptive analytics and actionable knowledge delivery categorisations align to the definitions put forward by Król & Zdonek (2020) and Menezes et al. (2019).

2.6 The analytics maturity path therefore shows an organisation’s analytics maturity stages beginning from the application of descriptive analytics (least mature) and ending with cognitive analytics (most mature).

2.7 For purposes of this paper, we will refer to the five stages outlined in paragraph 2.4 noting that nuances exist in the distinct analytics maturity categories as seen by the difference in the categories provided by Cao & Duan (2017) and Shmueli & Koppius (2011). However,

the five categories in paragraph 2.4 are widely accepted as distinct categories in the analytics continuum.

2.8 It is important to note that the evolution of the use of analytics in an organisation is not necessarily uniformly distributed. The implementation of organisational changes may vary in terms of the order and intensity, depending on both an organisation's specific characteristics and the broader external business context (Król & Zdonek, 2020; Menezes et al., 2019; Sun & Huo, 2019).

2.9 Assessing an organisation's analytics maturity across the analytics continuum can be conducted through various analytics maturity models discussed by various authors (Król & Zdonek, 2020; Lismont et al., 2017). Some of these models are discussed below.

2.10 Analytics maturity continuum

2.10.1 Analytics maturity can be described as the evolution of an organisation to integrate, manage, and leverage all relevant internal and external data sources into key decision points (Król & Zdonek, 2020). Barton & Court (2012) assert the importance of analytics maturity, calling it an increasingly important point of competitive differentiation. Competitive differentiation (a subset of competitive advantage as defined in paragraph 2.2) is defined as: an organisation outperforming a competitor in certain aspects of product design such that it experiences reduced sensitivity to sales volumes for other product-design related features (Dirisu et al., 2013). Barton & Court (2012) highlight that while the importance of advanced analytics is generally accepted by executives and senior management, most organisations are unclear on how to reach advanced levels on the analytics spectrum (ibid). Maturity models are used to guide a transformation process from rudimentary levels of analytics maturity to more advanced levels (Król & Zdonek, 2020). Once analytics maturity has been assessed and gaps have been identified, a roadmap can be developed to improve the analytics maturity of an organisation or industry (Barton & Court, 2012).

2.10.2 Most businesses have considerable experience in the use of descriptive and diagnostic analytics (Król & Zdonek, 2020) and research of analytics adoptions indicates that many organisations are still in the initial stages of the analytics maturity path (Lismont et al., 2017). These organisations are aiming to move to more advanced analytics that may increase the effectiveness of the actions they take (Król & Zdonek, 2020). Forecasts and simulations are examples of predictive, prescriptive, and cognitive analytics applications, resulting in optimised outcomes (Barton & Court, 2012).

2.10.3 An assessment of an organisation's analytics maturity can be carried out in a variety of ways (Lismont et al., 2017). Traditional methods of measuring analytics capacities include self-assessment, qualitative interviews, and quantitative studies (Król & Zdonek, 2020). However, a traditional approach to the assessment of analytics capacities has certain limitations, mainly due to the lack of an opportunity to verify them (ibid.). Self-assessment and quantitative studies are usually carried out using a checklist to determine whether specific technologies and analytics tools have been implemented (ibid.). At the same

time, however, they do not enable an assessment as to whether an organisation fully uses these tools to support business decisions, and whether they affect the organisation's activities (ibid.). An alternative to these methods is studies carried out using analytics maturity models (ibid.).

2.10.4 Maturity models have been designed to assess the analytics maturity of an organisation (Król & Zdonek, 2020). The maturity model serves as the scale for the appraisal of the position on the evolution path (Lismont et al., 2017). It provides criteria and characteristics that need to be fulfilled to reach a maturity level (ibid). During a maturity appraisal, a snapshot of the organisation regarding the given criteria is made (ibid).

2.10.5 Król & Zdonek (2020) provide an overview of eleven different types of analytics maturity models. The analytics models were selected based on an extensive review of scientific literature: Davenport et al. (2010) developed the DELTA model; Hamel (2019) developed the Web Analytics Maturity Model; Blast Analytics and Marketing developed the Blast Analytics Maturity Assessment Framework¹ based on the Web Analytics Maturity Model developed by Hamel (2019); Halper & Stodder (2014) developed the TDWI Analytics Maturity Model; Association Analytics developed the Data Analytics Maturity Model for Associations;² Gartner developed Gartner's Maturity Model for Data and Analytics;³ and SAS Institute developed the SAS Analytics Maturity Scorecard.⁴

2.10.6 Lismont et al. (2017) discuss five authors' approaches to analytics maturity models. This includes the models proposed by Saxena & Srinivasan (2013), Cosic et al. (2012), Comuzzi & Patel (2016), LaValle et al. (2011) and Ransbotham (2015).

2.10.7 Most of the models described in the literature aim to classify the stages of analytics maturity and are based on interpretation of survey and interview research to assess data warehousing and business intelligence (Lismont et al., 2017). Analytics maturity models thus provide frameworks to place an organisation on the analytics maturity curve (ibid.)

2.10.8 Figure 1 illustrates the analytics maturity continuum visually, as understood by the authors.

3. ADVANCED ANALYTICS TECHNIQUES

3.1 Advanced analytics is likely to become a decisive competitive asset in many industries and a core element in companies' efforts to improve performance (Barton & Court, 2012). Section 2 discussed analytics maturity models and how these are used to determine analytics adoption across various industries. A deep understanding of the problem being addressed as well as the techniques being utilised is necessary in order to solve problems in a manner that aligns with materiality and proportionality actuarial principles. The principle of materiality refers to the concept that an omission, understatement, or overstatement is material if the actuary expects it to affect either the user's decision-making or the user's

1 <https://www.blastanalytics.com/analytics-maturity-assessment>

2 <https://associationanalytics.com/2017/12/29/5-areas-assess-data-analytics-maturity-model/>

3 <https://www.gartner.com/en/newsroom/press-releases/2018-02-05-gartner-survey-shows-organizations-are-slow-to-advance-in-data-and-analytics>

4 https://www.sas.com/pl_pl/whitepapers/five-steps-to-analytical-maturity-106929.html

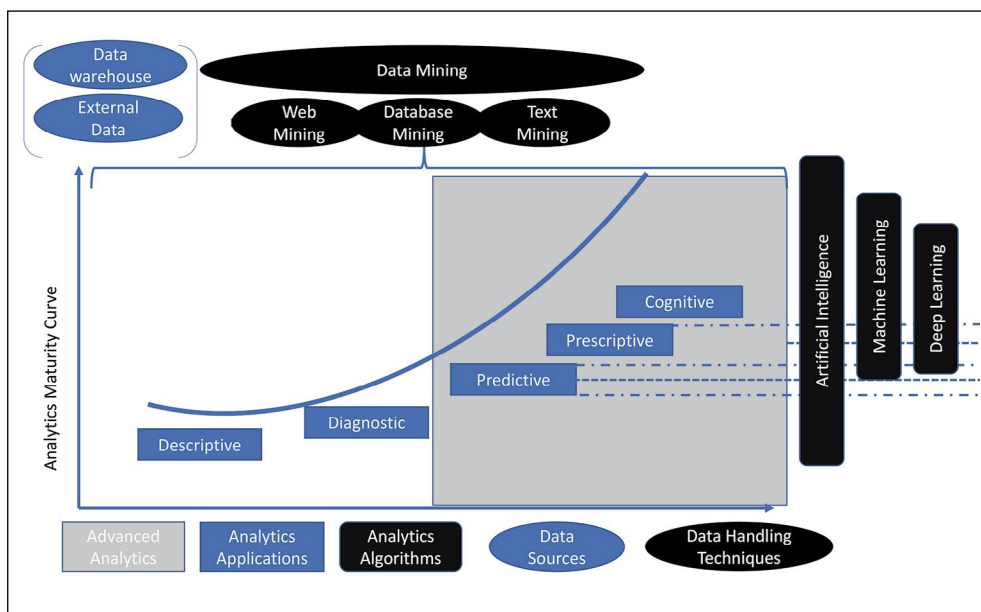


FIGURE 1. Analytics maturity continuum. Source: Authors

reasonable expectations and is generally considered amongst the actuarial community to be based on judgement (Herbers, 2002). On the other hand, proportionality principles consider that variables should be considered in comparison to the proportional impact on the overall result (Van Hulle, 2014). This section discusses the various techniques utilised across various industries to solve business challenges.

3.2 Advanced analytics is a general term which simply means applying various analytics techniques to data to answer questions or solve problems (Bose, 2008). Advanced analytics is not a tool or technology, but rather, a group of techniques that are used in combination with one another to gain information, analyse that information, and determine potential outcomes (ibid.).

3.3 This section explores commonly utilised mechanisms for data generation and commonly utilised analytics techniques: artificial intelligence, machine learning and deep learning.

3.4 Data integration and data mining

3.4.1 Data integration and data mining are the basis for analytics. The more information gathered and integrated, the easier pattern recognition and relationship identification will be (Bose, 2008). Current advanced analytics applications increasingly use data integration and data mining techniques to prepare data (Sparks et al., 2016). Various artificial

intelligence, machine learning and deep learning techniques can be utilised for data mining (Mitchell, 1997); these techniques are explored in detail below.

3.4.2 Data mining is a powerful technique for the automatic extraction of patterns, associations, changes, anomalies and significant structures from data (Bose, 2008). These uncovered patterns from data play a critical role in decision-making because they reveal areas for process improvement (Mitchell, 1997; Bose, 2008). Most of the value of data mining comes from using data-mining algorithms to improve the accuracy of analytics applications through enhancing understanding of the data and assisting with identification of areas for process improvement (ibid.).

3.4.3 Text mining and web mining are examples of data mining that have enabled the use of analytics to improve organisational performance through analysing unstructured customer data in the form of textual comments from survey research, e-mails and log files from web servers, which were previously unusable (Bose, 2008).

3.4.4 Sun & Huo (2019) define the relations among deep learning, machine learning, and artificial intelligence, which are mathematically represented as follows:

$$\text{deep learning} \subset \text{machine learning} \subset \text{artificial intelligence}.$$

That is, deep learning is a proper subset of machine learning, and machine learning is a proper subset of artificial intelligence (Russell & Norvig, 2010; Wu et al., 2019). This is expanded on in the sections that follow in order of increasing complexity.

3.5 Artificial intelligence

3.5.1 Artificial intelligence (AI) traditionally refers to an artificial creation of human-like intelligence that can learn, reason, plan, perceive, or process natural language (Dick, 2019). AI is considered to be a subset of computer science, focused on providing computers with the sophistication to act intelligently (Nilsson, 1982).

3.5.2 AI can therefore be defined as the universe of computing technology that exhibits anything remotely resembling human intelligence (Dick, 2019). AI systems can include anything from a problem-solving application that makes decisions based on complex rules (if/then logic) to a computer that develops the intelligence, free will, and emotions of a human being (Dick, 2019). Nilsson (1982) similarly defines AI techniques, namely: heuristic search, decision trees, game theory, rule-based deductive systems and object-oriented representations.

3.5.3 Artificial intelligence is further categorised into ‘narrow AI’ or ‘general AI’. Narrow AI is designed to perform specific tasks within a domain (e.g. real-time estimation of a mobile agent’s location using hidden Markov models (Beaulac & Larribe, 2017)). General AI is hypothetical and not domain specific but can learn and perform tasks anywhere to achieve true human-like intelligence (Lieto et al., 2018). All AI applications observed today are examples of narrow AI as we have not mastered replication of true human-like intelligence to date (Bundy, 2017).

3.6 Machine learning

3.6.1 Machine learning is a subset of AI application that improves through experience (Jordan & Mitchell, 2015). It reprogrammes itself, as it digests more data, to perform the specific task its designed to perform with increasingly greater accuracy (ibid.).

3.6.2 Rättsch (2004) explains machine learning uses pattern recognition; the modeller attempts to build algorithms capable of automatically constructing methods for distinguishing between different examples based on differentiating patterns. Examples given are: human faces, text documents, handwritten letters or documents, and the DNA sequences that cause certain diseases.

3.6.3 Analytics uses artificial intelligence and machine learning to build algorithms in order to extract knowledge through existing data, combine them and, as a result, forecast the future (Lopes et al., 2020). Mitchell (1997) explains machine learning is best understood in context of its role within computer science; examples include difficult-to-programme applications through rule-based logic which highlight the need for machine learning (e.g. facial recognition) and those which do not due to their simplistic and easily programmable underlying rule-based logic (e.g. matrix multiplication). These algorithms can be divided into two main categories: unsupervised and supervised learning.

3.6.4 Unsupervised learning is mostly known for characteristic extraction which can be very useful in different types of analysis as it will automatically identify structure in data (Lopes et al., 2020). The major unsupervised learning method is clustering, a process of grouping similar entities. The goal is to find similarities in the data and to group similar data points together (ibid.).

3.6.5 Supervised learning is typically done in the context of classification when input to output labels are mapped, or regression when input to a continuous output is mapped (ibid.). Supervised learning is used in healthcare to determine better clinical outcomes (Lopes et al., 2020). It includes use of techniques such as: linear regression, logistic regression, naive bayes, decision trees, nearest neighbour, random forests, support vector machine and neural network applications (ibid.).

3.6.6 Unsupervised learning can be used as part of the pre-processing step to reduce dimensionality or identify subgroups, summarising and explaining data features, making a significant contribution to the results. This can then lead to the application of supervised learning techniques. Supervised learning enhances the efficiency, both of processing and of the desired results, according to the objectives and the type of existing data (ibid.). To illustrate this difference, Maitland (2002) discusses the unsupervised technique of principal-components analysis which explains the variance-covariance structure of the original variables. Construction of principal components then assists with identifying subgroups in the data in order to make the modelling process easier due to the reduction in the size of the dataset. Reducing the number of variables of a dataset naturally comes at the expense of accuracy, but the trick in dimensionality reduction is to trade a little accuracy for the ability to process data and provide results more quickly. Smaller datasets are easier to explore and visualise and make analysing data much easier and faster for machine learning algorithms without extraneous variables to process (Wold et al., 1987).

3.6.7 More recently, semi-supervised learning has been introduced as a hybrid between unsupervised and supervised learning. The semi-supervised learning algorithm is trained upon a combination of labelled and unlabelled data and is suitable for scenarios where there is a lack of results in certain contexts (Lopes et al., 2020). Semi-supervised learning is currently being used in a range of smart healthcare applications (Zahin et al., 2019).

3.7 Deep learning

3.7.1 Deep learning, in its simplest form, consists of artificial neural networks with many hidden layers, allowing the models to discover intricate structure in large datasets (Smith et al., 2016).

3.7.2 Since 2006, deep learning has been increasing in popularity (ibid.). Several factors have contributed to this revival. Unsupervised methods have been used to pre-train the networks, improving the feasibility of feature detection; and graphical processing units have been used to train the networks, making training of large networks possible (ibid.).

3.7.3 Deep learning is a subset of machine learning originating from artificial neural networks, in which feedforward neural networks are combined with many hidden layers of logic (Zhang et al., 2017).

3.7.4 Figure 2 illustrates the relationship between artificial intelligence, machine learning and deep learning as defined by Sun & Huo (2019), illustrated by the authors.

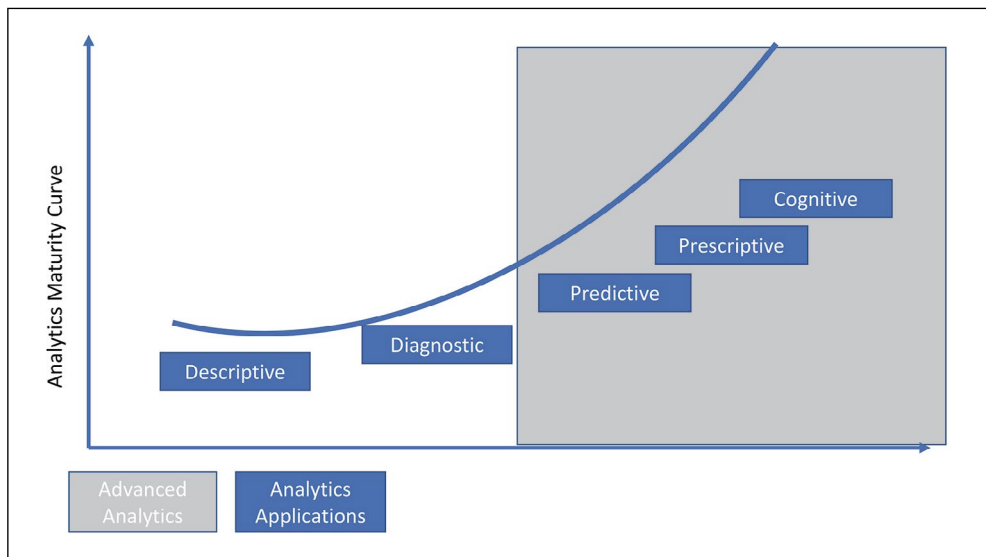


FIGURE 2. Relationship between artificial intelligence, machine learning and deep learning
(Authors' reflection of definitions by Sun & Huo, 2019)

4. APPLICATIONS OF ADVANCED ANALYTICS IN HEALTHCARE

4.1 Various models to assess analytics maturity exist and have been outlined in Section 2. The purpose of any analytics maturity model is to assist with gap identification in

the application of analytics (Król & Zdonek, 2020). As discussed by Lismont et al. (2017) and Król & Zdonek (2020) in paragraph 2.10.3, one method for assessing an organisation's maturity is through qualitative research. Since the aim is to understand how a community or individuals within it perceive the extent of the application of analytics, qualitative methods are often appropriate (McCusker & Gunaydin, 2015).

4.2 This section considers advanced analytics applications in the healthcare space and, in this context, an analogy between the 'organisation' referred to by Król & Zdonek (2020) and the 'healthcare system' can be drawn. Islam et al. (2018) conducted a qualitative literature review and examined analytics in two areas, namely clinical and administrative decision-making. In this paper, a broader perspective is provided through inclusion of additional healthcare system components, categorised by the authors, which include: patient experience, patient behaviour, medical treatment (diagnosis, lab and radiology), healthcare resource allocation, billing, disease modelling and health economics. These disciplines appeared as common themes in the literature review. Utilising these disciplines, this research examines analytics in broader healthcare disciplines while categorising each application according to the placement on the analytics maturity curve and the sophistication of the analytics technique utilised. The relationship between analytics maturity and analytics techniques in the healthcare space is then explored.

4.3 Health economics

4.3.1 Choi et al. (2016) introduce health economics as one of the main emerging fields of economics. They further discuss the potential of using a combined analytics and health economics approach to propose a mutually beneficial public-private partnership healthcare system.

4.3.2 Rawlins et al. (2010) discuss the key role health economics currently plays in cost-benefit, cost-effectiveness, cost-minimisation, cost-of-illness and cost-utility analyses. Rawlins et al. (2010) further describe the cost-effectiveness measure as being the industry preferred method to inform health economics-based decision-making. Cost-effectiveness measures make use of economic modelling of quality adjusted life years (QALYs) (ibid.). This is supported by Marshall et al. (2015) who state that typically traditional economic modelling methods are used to conduct health economic analyses.

4.4 Medical treatment (including diagnosis)

4.4.1 Stochastic trees have been utilised to enhance the decision-making process in medical treatment procedures (Kudyba & Gregorio, 2010).

4.4.2 Data mining of laboratory tests and radiology examinations provides vital information for physicians to administer corresponding treatment plans, where breakdowns or inhibitors of these processes can adversely affect timely treatment activities which are depicted in corresponding outcome metrics (Kudyba & Gregorio, 2010).

4.4.3 Lopes et al. (2020) discuss analytics applications utilised to detect cancer at an earlier stage, based on genetic and non-genetic factors. In a recent study, a hybrid

system was developed with data-mining algorithms, to build a predictive model capable of distinguishing between breast cancer and non-breast cancer diagnoses with 100% accuracy (ibid.). Lopes et al. (2020) also discuss a study conducted in Taiwan by a team of researchers who utilised data-mining techniques based on logistic regression to predict the survival rate among oral cancer patients, with 95.7% accuracy.

4.4.4 Other studies utilising similar techniques to diagnose leukaemia patients and improve accuracy of early detection of heart disease are also outlined (ibid.). Applications of analytics in each study varied, including analysis of multiple risk factors to predict the likelihood of disease positivity and the generation of scorecards to determine the likelihood of certain outcomes.

4.4.5 Wesdorp et al. (2021) conducted a review on the value of radiomics in predicting response to treatment in patients with gastrointestinal tumours. The review found radiomics has great potential to predict patient response to treatment and therefore improve patient selection and early adjustment of treatment strategy in a non-invasive manner (ibid.).

4.5 Healthcare resource allocation

4.5.1 Raghupathi & Raghupathi (2014) conducted a literature review on analytics applications and their potential in the healthcare space. Their findings identify hospital management processes (including healthcare practitioner allocation) to be a primary area where analytics can be applied to improve efficacy.

4.5.2 Operational efficiency for healthcare organisations refers to more accurately identifying where resources are required and how to allocate resources effectively to meet arising demand. Resources in this context include financial, human and treatment resources (Kudyba & Gregorio, 2010).

4.5.3 David et al. (2019) studied a commercial insurer-driven intervention to improve resource allocation. This was structured as a claims-based algorithm to determine a member level healthcare utilisation risk score in order to identify members most likely to benefit from care management teams. Focusing resources on those with predicted greater need leads to improved outcomes for the same level of resource input as compared to a less focussed approach.

4.6 Patient experience

4.6.1 Kudyba & Gregorio (2010) discuss a case study approach to illustrate the effectiveness of the neural network analytic method to identify factors within the patient treatment process that produce high variances in performance metrics; factors included supply chains and patient flow management (ibid.).

4.6.2 Yeh et al. (2016) explore the potential of radiologists utilising social media platforms to engage with patients. Specific focus is given to current examples of physicians using of mineable social media content (an example of web mining) to provide patient-centred communication and information exchange to improve the overall patient experience (ibid.).

4.6.3 Ranard et al. (2016) explain how Yelp reviews of hospital care are being utilised to supplement and inform traditional surveys of the patient experience. Yelp is defined

as a popular American real-time online rating platform and as at 2016 Yelp was the most widely used freely available commercial website in the United States for hospital ratings (ibid.). Natural language processing is used to conduct text mining of all Yelp narrative reviews to provide segmented underlying topics (ibid.).

4.6.4 Understanding patient experience is important for improving healthcare outcomes since improved experience is associated with greater compliance with treatment as well as driving overall healthcare system transformation (Browne et al., 2010)

4.7 Patient behaviour

4.7.1 In healthcare, data analytics have been used to predict which characteristics of people are associated with noncompliance with healthcare treatment procedures, allowing for more personalised interventions (Kudyba & Gregorio, 2010). Kankanhalli et al. (2016) state that it is possible to determine patient behaviour and sentiment from wearable devices, social media posts and web pages. Rose & Burgin (2014) similarly discuss monitoring of patient behaviour as a mechanism to manage healthcare delivery costs through administration and delivery (Hermon & Williams, 2014). Kudyba & Gregorio (2010) add that contextualised patient behaviour information and preventive suggestions can be made available to patients by associating personal data with locations, health indicators and weather conditions.

4.7.2 Krishnan et al. (2015) found that it is possible to change patient behaviour using strategies such as phone reminders and educational programmes to influence factors such as the rate of non-attendance of follow-up treatment. Strategies taken were informed by various regression models.

4.7.3 Vry et al. (2016) explore using cross-sectional patient experience survey data to identify healthcare-seeking behaviour. Patient characteristics were used as independent variables for regression analyses (ibid.). The study determined patient characteristic differences influencing healthcare-seeking behaviour (ibid.). Vry et al. (2016) further assert that the research can be used to improve barriers to healthcare access by identifying individuals in need of prompting to seek timely healthcare services.

4.8 Financial management

4.8.1 Data-mining techniques enable decision-makers to identify patterns in clinical-, claims- and activity-based historical data, to better identify and understand explanatory relationships between variables that describe operational processes (Kudyba & Gregorio, 2010).

4.8.2 Branting et al. (2016) present a novel approach to utilising analytics, specifically: network algorithms to identify healthcare fraud risk in insurance pools. The algorithms considered included: calculation of behavioural similarity to known fraudulent and non-fraudulent healthcare providers with respect to measurable healthcare activities; and estimation of likelihood of fraud using geospatial analysis on shared practice locations and other addresses (ibid.).

4.8.3 Mehta & Pandit (2018) and Raghupathi & Raghupathi (2014) highlight claims data as a central source of healthcare data, explaining healthcare data sources are

disorganised and fragmented having different structures and forms. Mehta & Pandit (2018) discuss the need for all data sources to be integrated to provide a holistic view of the patient. Specific focus is given to the use of holistic patient data to improve health-process efficiency and reduction of healthcare costs through improved documenting and reporting (ibid.)

4.8.4 Similarly, Chen et al. (2020) discuss the integral role analysis of claims information plays in assisting with reducing administrative costs and decreasing fraud, waste, and abuse. The applications of analytics in financial management of healthcare insurance risk pools is critical for preserving financial integrity and sustainability and hence promoting access to healthcare cover.

4.9 Disease modelling

4.9.1 Reddy et al. (2011) utilise advanced analytics to facilitate an understanding of HIV progression and highlight the factors that influence disease progression. This work can be used to develop new treatment strategies.

4.9.2 Barry et al. (2018) explore the current state of the field of outbreak analytics—defined as an emerging area of data science focused on the technological and methodological aspects of the outbreak data pipeline. Barry et al. (2018) discuss current approaches to disease modelling, particularly in the context of a pandemic. This includes database design and mobile technology, frequentist statistics and maximum-likelihood estimation, interactive data visualisation, geo-statistics, graph theory, Bayesian statistics, mathematical modelling, genetic analyses and evidence synthesis approaches.

4.9.3 Giordano et al. (2020) similarly discuss use of the multistate susceptible-infected-removed (SIR) model (a predictive mathematical model for epidemics) as being fundamental to understanding the course of the Covid-19 pandemic and therefore enabling planning of appropriate control strategies. These models have been constructed at rapid pace from various data sets which are both structured and unstructured.

4.9.4 These are some notable examples from the literature illustrating that analytics applications are present and highly utilised in healthcare and are rapidly becoming an indispensable tool for clinicians and risk managers in ensuring interventions are appropriate and effective in improving health outcomes. However, while there is research evidence supporting use of these techniques, what is not addressed is the relationship between the sophistication of the application and the sophistication of the technique as described in the current literature. This paper addresses this gap by examining this relationship and illustrating diagrammatically the difference between analytics applications and analytics techniques. Through understanding of these terms this paper highlights the need to use principles of materiality and proportionality when utilising analytics to support decision-making.

5. KEY FINDINGS

5.1 Table 1 summarises the various applications and techniques in industry as categorised by the authors.

TABLE 1. Summary of literature review classified integrating analytics maturity and analytics technique frameworks

Discipline	Use case	Application	Technique	Reference
Patient experience	Optimal patient pathway: neural network	Cognitive	Artificial intelligence	Kudyba & Gregorio (2010)
	Patient care: context-sensitive decision support	Unknown	Unknown	Yeh et al. (2014)
	Patient centred communication: Web mining social media content	Descriptive	Artificial intelligence	Ranard et al. (2016)
	Hospital care process improvement	Descriptive	Machine learning	Browne et al. (2010)
Patient behaviour	Determine characteristics of patients associated with noncompliance	Diagnostic	Machine learning	Kudyba & Gregorio (2010)
	Determine patient behaviour and sentiment	Diagnostic	Machine learning	Kankanhalli et al. (2016)
	Monitoring patient behaviour to manage healthcare claims costs	Diagnostic	Machine learning	Rose & Burgin (2014)
	Changing patient behaviour	Predictive	Machine learning	Krishnan et al. (2015)
	Understanding health-seeking patient behaviour	Predictive	Artificial intelligence	Vry et al. (2016)
Medical treatment	Treatment procedure: stochastic trees	Cognitive	Artificial intelligence	Kudyba & Gregorio (2010)
	Lab tests: rule-based logic on outcomes	Diagnostic	Not disclosed	Kudyba & Gregorio (2010)
	Diagnosis: neural network	Cognitive	Machine learning	Lopes et al. (2020)
	Predicting patient response to treatment	Prescriptive	Artificial intelligence	Wesdorp et al. (2021)
Resource allocation	Improving hospital management processes	Diagnostic	Artificial intelligence	Raghupathi & Raghupathi (2014)
	Identifying sources of resource demand to improve hospital efficiency	Descriptive	Artificial intelligence	Kudyba & Gregorio (2010)
	Healthcare utilisation risk score determination to manage claims costs	Predictive	Artificial intelligence	David et al. (2019)
Financial management	Data mining	Descriptive	Machine learning	Kudyba & Gregorio (2010)
	Network algorithms to identify health fraud risk	Predictive	Machine learning	Branting et al. (2016)
Disease modelling	Markov process to model disease progression	Descriptive	Artificial intelligence	Reddy et al. (2011)
	Mathematical modelling to conduct outbreak analytics	Predictive	Artificial intelligence	Barry et al. (2018)
	Markov process to model Covid-19 progression	Descriptive	Artificial intelligence	Giardano et al. (2020)
Health economics	Health technology assessments	Descriptive	Artificial intelligence	Choi et al. (2016)
	Cost-benefit, cost-effectiveness, cost-minimisation, cost-of-illness, and cost-utility analyses	Descriptive	Artificial intelligence	Rawlins et al. (2010)

5.2 This literature review has aimed to identify the gaps between analytics techniques and applications in the healthcare industry. A total of 23 use cases have been analysed of which 21 provided sufficient data to classify the use case using the application and technique frameworks introduced in sections 2 and 3 respectively. From this, the following is identified:

5.2.1 Most applications relate to the most rudimentary categories on the analytics maturity continuum (40% descriptive and 20% diagnostic). A minority of use cases considered more sophisticated applications on the analytics maturity continuum (5% prescriptive and 5% cognitive). This highlights the potential to improve the adoption of more sophisticated analytics applications in healthcare industry.

5.2.2 Most use cases utilised artificial intelligence techniques (60%) with the remainder utilising machine learning (40%). No use cases utilised deep learning techniques. This highlights the potential to utilise more sophisticated techniques in the healthcare industry.

5.2.3 Artificial intelligence techniques were utilised by 75% of descriptive applications; machine learning techniques were utilised by 25% of descriptive applications. Artificial intelligence techniques were utilised by 25% of diagnostic applications; machine learning techniques were utilised by 75% of diagnostic applications. Artificial intelligence techniques were utilised by 50% of predictive applications; machine learning techniques were utilised by 50% of predictive applications. Both prescriptive and cognitive applications only utilised artificial intelligence techniques. No direct relationship appears to exist between the sophistication of application and the sophistication of the technique utilised; the proportion of more sophisticated techniques utilised does not increase as the sophistication of the application increases on the analytics maturity continuum.

5.2.4 Most disciplines included in the literature review had three or more observable use cases whereas financial management and health economics had only two. This potentially highlights two areas where there is greater opportunity for analytics adoption. This paper is part of a larger body of research which is exploring this further.

6. DISCUSSION

6.1 The principles of the Actuarial Society of South Africa (ASSA) code of professional conduct require actuaries to undertake to deliver, throughout their careers, specialist and up-to-date actuarial expertise that is ethical and subject to professional oversight (Lowther & McMillan 2014). Accordingly, the Code requires members to undertake to deliver a quality service (ibid.). As asserted by Barton & Court (2012), advanced analytics is likely to become a decisive competitive asset in many industries and a core element in companies' efforts to improve performance. Actuaries should therefore remain abreast of the various analytics applications and tools, technologies and algorithms available to inform decision-making and problem solving. This would include keeping up to date on legal considerations associated with the use of AI and dealing with confidential and sensitive information. There is likely to be a reasonable amount of intersectionality with the work of academics in the medical ethics and legal fields.

6.2 Terblanche (2009) discusses demand for actuarial resources in the context of changes in the financial environment, the ability of other professions to solve problems and the expansion of the role of actuaries into wider fields. As organisations increase their use of analytics to inform decision-making (Król & Zdonek, 2020), actuaries need to ensure they are able to compete in an ever-changing world where the lines between professions such as engineering and data science are more blurred. The benefit of working in multi-disciplinary teams is also becoming increasingly apparent as actuarial professional discipline and judgement can be combined with various technical inputs to analytics design.

6.3 A clear distinction exists between analytics applications and techniques. Analytics applications relate to the nature of the business question being asked whereas analytics techniques relate to the methodology used to answer the question. Analytics applications therefore consider what happened (descriptive), why did it happen (diagnostic), what may happen in future (predictive), what actions should be taken in future (prescriptive), and what actions should be taken in future taking into account real-time monitoring (cognitive). Analytics techniques consider the specific programming technique utilised (artificial intelligence, machine learning or deep learning).

6.4 Analytics maturity models can be utilised to place an organisation's analytics maturity on the analytics maturity continuum. This is in effect a mechanism to measure or rank the extent to which analytics is being used to inform decision-making within an organisation (or industry). The purpose of measuring the extent to which analytics is applied in decision-making is to identify gaps and assist with putting in place a strategy to improve organisation-wide analytics adoption.

6.5 Understanding the difference between various analytics techniques is necessary to ensure that the optimal technique is utilised when considering the actuarial principles of materiality and proportionality. More complex algorithms require longer processing time and higher computing power which are associated with additional costs. An organisation should avoid heavy capital expenditure on technology to support more sophisticated analytics techniques if the same or similar results can be provided utilising less sophisticated methods. Similarly the benefit of investing in building analytic capacity needs to be optimised by ensuring that the full potential of applying techniques to risk management is realised. Sophistication should be introduced when there is a substantial improvement in accuracy of results.

6.6 A complex advanced analytics technique can therefore be used to address a business challenge that is solved by descriptive applications i.e. answering, "what happened". For example, a self-organising map (a type of artificial neural network) can be utilised to cluster consumer behaviour into homogenous groups in order to understand historical behavioural choices. The complexity of the technique utilised is not directly correlated with the purpose (application) for which it is utilised. A deep understanding of the problem being addressed

as well as the technique being utilised is necessary in order to solve problems in a manner that align with materiality and proportionality actuarial principles. Therefore, from the analysis in this paper it is concluded that, while it is important to understand the placement on the analytics maturity curve and the level of sophistication of techniques applied, gap identification must consider the appropriateness of using more sophisticated techniques to address healthcare-related challenges.

6.7 Figure 3 illustrates the relationship between analytics applications on the analytics maturity curve and analytics techniques.

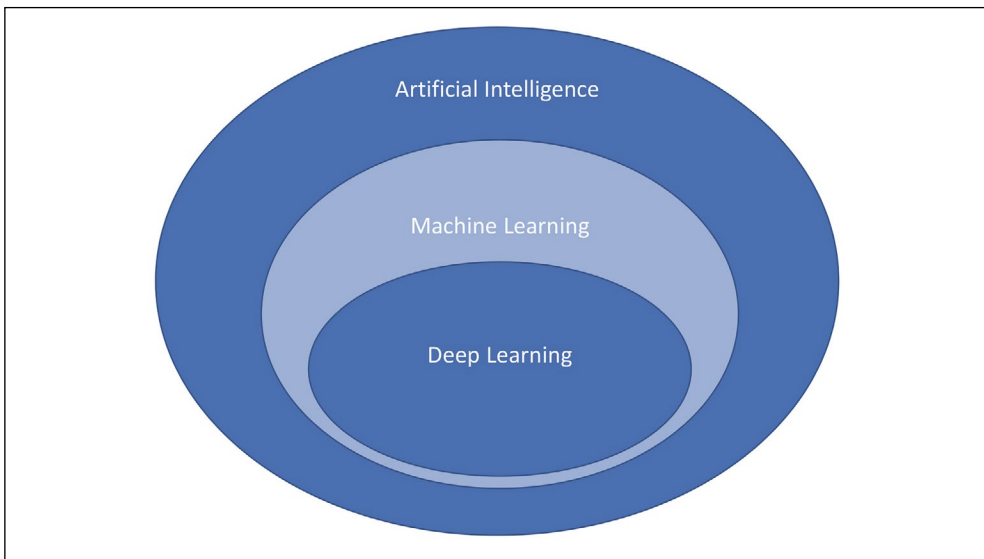


FIGURE 3. Linking analytics maturity curve (application) with analytics technique

6.8 Based on the literature review, the authors discuss analytics applications (the ‘what’) and analytics techniques (the ‘how’) separately. Research thus far has not considered an integrated view which highlights when it is most appropriate to utilise the techniques. The literature review has been conducted through desktop research using the following keywords: ‘advanced analytics’; ‘analytics maturity models’; ‘analytics techniques’; ‘machine learning’; ‘artificial intelligence’; ‘deep learning’.

6.9 In the context of healthcare applications, no direct relationship appears to exist between the sophistication of the application and the sophistication of the technique utilised since the proportion of more sophisticated techniques utilised does not appear to increase as the sophistication of the application increases on the analytics maturity continuum.

6.10 Most healthcare examples included in the literature review had three or more observable use cases whereas financial management and economics had only two. This

potentially highlights two disciplines where analytics adoption lags compared to other disciplines. This paper is part of a larger body of work which explores this hypothesis.

7. CONCLUSION

7.1 The use of analytics in healthcare is becoming more prevalent due to the volumes of data involved as well as increasing accessibility of processing power to support more advanced techniques. It is apparent that there is an opportunity for these techniques to be applied to more advanced applications to realise the full potential in terms of risk management and enhancing health outcomes.

7.2 It is important for actuaries to remain abreast with the latest industry trends commonly used to inform decision-making. Analytics and, more specifically, advanced analytics has fast become an important strategic decision-making tool for organisations in various industries, and in healthcare in particular. Actuaries need to ensure they can understand and apply the various techniques available to solve business problems optimally and to apply appropriate judgement in the interpretation of results.

7.3 A deep understanding of the problem statement being addressed as well as the analytics techniques being utilised is necessary in order to solve problems in a manner that aligns with materiality and proportionality actuarial principles. A clear distinction has been established between analytics applications and analytics techniques.

7.4 Further, no direct relationship appears to exist between the sophistication of the application and the sophistication of the technique utilised. There is therefore potential for more sophisticated applications in the healthcare industry—the techniques utilised should be considered in context of actuarial materiality and proportionality principles.

7.5 This paper forms part of a larger body of research. Through this research, the following foundational principles have been established:

- There is a difference between analytics applications and techniques;
- Outcomes can be optimised by identifying in which cases particular techniques are applicable; and
- Researchers and healthcare practitioners can benefit from the appropriate use of analytics techniques.

7.6 The research that has been done in this area to date has a strong qualitative focus in regard to analytics maturity frameworks and a review of analytics techniques utilised in practice. Empirical evidence highlighting when best to apply the techniques in real world application remains an area for future research.

REFERENCES

- Barry, A, Ahuka-Mundeke, S, Ahmed, YA, Allaranger, Y, Anoko, J, Archer, BN, Abedi, AA, Bagaria, J, Belizaire, MRD, Bhatia, S & Bokenge, T (2018). Outbreak of Ebola virus disease in the Democratic Republic of the Congo, April–May, 2018: An epidemiological study. *The Lancet*, **392**(10143), 213–21
- Barton, D & Court, D (2012). Making advanced analytics work for you. *Harvard Business Review*, **90**(10), 78–83
- Beaulac, C & Larribe, F (2017). Narrow artificial intelligence with machine learning for real-time estimation of a mobile agent's location using hidden Markov models. *International Journal of Computer Games Technology*, 2017
- Bose, R (2008). Competitive intelligence process and tools for intelligence analysis. *Industrial management & data systems* **108**(4), 510–28. <https://doi.org/10.1108/02635570810868362>
- Branting, LK, Reeder, F, Gold, J & Champney, T (2016). Graph analytics for healthcare fraud risk estimation. 2016 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM) (pp. 845–51). IEEE
- Browne, K, Roseman, D, Shaller, D & Edgman-Levitan, S (2010). Measuring patient experience as a strategy for improving primary care. *Health Affairs* **29**(5), 921–25
- Bundy, A (2017). Preparing for the future of artificial intelligence. *AI & Society* **32**, 285–7. <https://doi.org/10.1007/s00146-016-0685-0>
- Cao, G & Duan, Y (2017). How do top-and bottom-performing companies differ in using business analytics? *Journal of Enterprise Information Management* **30**(6)
- Chen, YW, Stanley, K & Att, W (2020). Artificial intelligence in dentistry: Current applications and future perspectives. *Quintessence Int* **51**(3), 248–57
- Choi, L, Lai, D & Lai, T (2016). Health analytics, economics and medicine toward a 21st century health care system. *Health* **8**, 428–43
- Comuzzi, M & Patel, A (2016). How organisations leverage big data: A maturity model. *Industrial Management & Data Systems* **116**(8), 1468–92
- Cosic, R, Shanks, G & Maynard, S (2012). Towards a business analytics capability maturity model. 23rd Australasian Conference on Information Systems
- Davenport, TH, Harris, JG & Morison, R (2010). *Analytics at Work*. Harvard Business School Press
- David, G, Smith-McLallen, A & Ukert, B (2019). The effect of predictive analytics-driven interventions on healthcare utilization. *Journal of Health Economics*, **64**, 68–79
- Dick, S (2019). *Artificial intelligence*. MIT Press
- Dirisu, JI, Iyiola, O & Ibiidunn, OS (2013). Product differentiation: A tool of competitive advantage and optimal organizational performance (A study of Unilever Nigeria). *European Scientific Journal*, **9**(3), 258–81
- Ghasemaghaci, M, Ebrahimi, S & Hassanein, K, (2018). Data analytics competency for improving firm decision making performance. *The Journal of Strategic Information Systems* **27**(1), 101–13
- Giordano, G, Blanchini, F, Bruno, R, Colaneri, P, Di Filippo, A, Di Matteo, A & Colaneri, M (2020). Modelling the COVID-19 epidemic and implementation of population-wide interventions in Italy. *Nature Medicine* **26**(6), 855–60
- Halper, F & Stodder, D (2014). TDWI analytics maturity model guide. *TDWI Research*, 1–20

- Hameed, I (2019). Sources of business competitive advantage: A review. *Journal of Business and Economics* **5**(2), 222–33
- Hamel, S (2009). The Web Analytics Maturity Model. A strategic approach based on business maturity and critical success factors. <https://goo.gl/96nPyr> (accessed on 25 January 2021)
- Herbers, JA (2002). Materiality and statements of actuarial opinion. In: Casualty Actuarial Society Forum, pp. 103–38. 2002.
- Hermion, R & Williams, PA (2014). Big data in healthcare: What is it used for? 3rd Australian eHealth Informatics and Security Conference, Edith Cowan University, Joondalup Campus, Perth
- Islam, MS, Hasan, MM, Wang, X, Germack, HD & Noor-E-Alam, M (2018). A systematic review on healthcare analytics: application and theoretical perspective of data mining. *Healthcare* **6**(2), 54
- Jordan, MI & Mitchell, TM (2015). Machine learning: Trends, perspectives, and prospects. *Science* **349**(6245), 255–60
- Kankanhalli, A, Hahn, J, Tan, S & Gao, G (2016). Big data and analytics in healthcare: Introduction to the special section. *Information Systems Frontiers* **18**(2), 233–35
- Krishnan, A, Ferro, EG, Weikum, D, Vagenas, P, Lama, JR, Sanchez, J & Altice, FL (2015). Communication technology use and mHealth acceptance among HIV-infected men who have sex with men in Peru: implications for HIV prevention and treatment. *AIDS Care* **27**(3), 273–82
- Król, K & Zdonek, D (2020). Analytics maturity models: An overview. *Information* **11**(3), 142
- Kudyba, S & Gregorio, T (2010). Identifying factors that impact patient length of stay metrics for healthcare providers with advanced analytics. *Health Informatics Journal* **16**(4), 235–45
- LaValle, S, Lesser, E, Shockley, R, Hopkins, MS & Kruschwitz, N (2011). Big data, analytics and the path from insights to value. *MIT Sloan Management Review* **52**(2), 21–32
- Lieto, A, Bhatt, M, Oltramari, A & Vernon, D (2018). The role of cognitive architectures in general artificial intelligence. *Cognitive Systems Research* **48**, 1–3
- Lismont, J, Vanthienen, J, Baesens, B & Lemahieu, W (2017). Defining analytics maturity indicators: A survey approach. *International Journal of Information Management* **37**(3), 114–24
- Lopes, J, Guimarães, T & Santos, MF (2020). Predictive and prescriptive analytics in healthcare: A survey. *Procedia Computer Science* **170**, 1029–34
- Lowther, MW & McMillan, WJ (2014). Authentic professional development: Key to quality service delivery. *South African Actuarial Journal* **14**(1), 1–18
- Maitland, AJ (2002). Interpolating the South African yield curve using principal-components analysis: A descriptive approach. *South African Actuarial Journal* **2**(1), 129–45
- Marshall, DA, Donald, F, Lacny, S, Reid, K, Bryant-Lukosius, D, Carter, N, Charbonneau-Smith, R, Harbman, P, Kaasalainen, S, Kilpatrick, K & Martin-Misener, R (2015). Assessing the quality of economic evaluations of clinical nurse specialists and nurse practitioners: A systematic review of cost-effectiveness. *NursingPlus Open* **1**, 11–17
- McCusker, K & Gunaydin, S (2015). Research using qualitative, quantitative or mixed methods and choice based on the research. *Perfusion* **30**(7), 537–42
- Mehta, N & Pandit, A (2018). Concurrence of big data analytics and healthcare: A systematic review. *International Journal of Medical Informatics* **114**, 57–65
- Menezes, BC, Kelly, JD, Leal, A & Le Roux, GC (2019). Predictive, prescriptive and detective analytics for smart manufacturing in the information age. *IFAC PapersOnLine* **52**(1), 568–73

- Mitchell, TM (1997). Does machine learning really work? *AI magazine* **18**(3), 11–20
- Nilsson, NJ (1982). *Principles of artificial intelligence*. Springer Science & Business Media
- Porter, ME (1989). How competitive forces shape strategy. *Readings in Strategic Management* (133–43). Palgrave, London
- Raghupathi, W & Raghupathi, V (2014). Big data analytics in healthcare: promise and potential. *Health information science and systems* **2**, 1–10
- Ranard, BL, Werner, RM, Antanavicius, T, Schwartz, HA, Smith, RJ, Meisel, ZF, Asch, DA, Ungar, LH & Merchant, RM (2016). Yelp reviews of hospital care can supplement and inform traditional surveys of the patient experience of care. *Health Affairs* **35**(4), 697–705
- Ransbotham, S, Kiron, D & Prentice, PK (2015). The talent dividend. *MIT Sloan Management Review* **56**(4), 1–12
- Rätsch, G (2004). A brief introduction into machine learning. Friedrich Miescher Laboratory of the Max Planck Society
- Rawlins, M, Barnett, D & Stevens, A (2010). Pharmacoeconomics: NICE's approach to decision-making. *British Journal of Clinical Pharmacology* **70**(3), 346
- Reddy, T, Mwambi, H & Ndung'u, T (2011). Modelling HIV progression using multistate Markov models. Annual Proceedings of the South African Statistical Association Conference (Vol. 2011, No. con-1, 100–117). South African Statistical Association (SASA)
- Rose, J & Burgin, M (2014). Disrupting health care through big data and predictive analytics. *Managed Care Outlook* **27**(1), 11
- Russell, S & Norvig, P (2010). *Intelligence artificielle: Avec plus de 500 exercices*. Pearson Education France
- Saxena, R & Srinivasan, A (2013). *Business analytics: A practitioner's guide* (Vol. 186). Springer New York
- Shmueli, G & Koppius, OR (2011). Predictive analytics in information systems research. *MIS Quarterly*, 553–72
- Smith, ML, Beyers, FJC & De Villiers, JP (2016). A method of parameterising a feed forward multi-layered perceptron artificial neural network, with reference to South African financial markets. *South African Actuarial Journal* **16**(1), 35–67
- Sparks, TD, Gaultois, MW, Oliynyk, A, Brgoch, J & Meredig, B (2016). Data mining our way to the next generation of thermoelectrics. *Scripta Materialia* **111**, 10–15
- Sun, Z & Huo, Y (2019). The spectrum of big data analytics. *Journal of Computer Information Systems* **61**(2), 154–62
- Terblanche, W (2009). Demand for actuarial resources in South Africa. *South African Actuarial Journal* **9**(1), 1–52
- Van Hulle, K (2014). The actuarial function under Solvency II. In Actuarial Conference for Insurance Supervisors
- Vry, J, Gramsch, K, Rodger, S, Thompson, R, Steffensen, BF, Rahbek, J, Doerken, S, Tassoni, A, Beytía, MDLA, Guerguelcheva, V & Chamova, T (2016). European cross-sectional survey of current care practices for Duchenne muscular dystrophy reveals regional and age-dependent differences. *Journal of Neuromuscular Diseases* **3**(4), 517–27

- Watson, HJ (2017). Preparing for the cognitive generation of decision support. *MIS Quarterly Executive*, **16**(3), 153–69
- Wesdorp, NJ, Hellingman, T, Jansma, EP, van Waesberghe, JH, Boellaard, R, Punt, CJ, Huiskens, J & Kazemier, G (2021). Advanced analytics and artificial intelligence in gastrointestinal cancer: a systematic review of radiomics predicting response to treatment. *European Journal of Nuclear Medicine and Molecular Imaging* **48**(6), 1785–94
- Wu, C, Buyya, R & Ramamohanarao, K (2019). Cloud pricing models: Taxonomy, survey, and interdisciplinary challenges. *ACM Computing Surveys (CSUR)* **52**(6), 1–36
- Wold, S, Esbensen, K & Geladi, P (1987). Principal component analysis. *Chemometrics and Intelligent Laboratory Systems* **2**(1–3), 37–52
- Yeh, J, Doshi, AM, Hawkins, CM, Heilbrun, ME & Smith, SE (2016). Big data and the future of radiology informatics. *Academic radiology* **23**(1), 30–42
- Yoon, SN, Lee, D & Schniederjans, M (2016). Effects of innovation leadership and supply chain innovation on supply chain efficiency: Focusing on hospital size. *Technological Forecasting and Social Change*, 113, 412–21
- Zahin, A, Tan, LT & Hu, RQ (2019). Sensor-based human activity recognition for smart healthcare: A semi-supervised machine learning. International Conference on Artificial Intelligence for Communications and Networks (pp. 450–472). Springer, Cham
- Zhang, L, Tan, J, Han, D & Zhu, H (2017). From machine learning to deep learning: progress in machine intelligence for rational drug discovery. *Drug Discovery Today* **22**(11), 1680–85

The contribution of insurers to systemic risk: A practical framework for regulators

By RD Rusconi, FJC Beyers and NM Walters

Submission date 27 April 2023

Acceptance date 8 November 2023

ABSTRACT

While insurers are not typically the most significant contributors to systemic risk, their actions and behaviour may materially contribute to such risk. This study considers the models that may be used to detect systemic risk originating in the insurance market and proposes a framework for identifying and classifying the sources of systemic risk attributable to insurers. It applies this framework to the insurance market in South Africa, in the process providing practical recommendations for consideration by all regulators.

JEL CLASSIFICATION

C19, C63, D62, G22, G28

KEYWORDS

Insurance, systemic risk, risk classification and modelling

CONTACT DETAILS

RD Rusconi, Department of Actuarial Science, University of Pretoria, Pretoria, South Africa

Email: robert.rusconi@up.ac.za; ORCID: 0000-0002-9566-5405

FJC Beyers, Department of Actuarial Science, University of Pretoria, Pretoria, South Africa

Email: conrad.beyers@up.ac.za; ORCID: 0000-0002-2870-4718

NM Walters, Department of Actuarial Science, University of Pretoria, Pretoria, South Africa

Email: nadine.walters@up.ac.za

1. INTRODUCTION

1.1 Systemic risk is the possibility of weakness of or contagion within the financial system, with potential spillover into the wider economy (Acharya et al., 2017; Bisias et al., 2012; Kessler, 2014; Weiß & Mühlhnickel, 2014). Financial-sector regulators typically include among their objectives the goal of identifying and mitigating the potential for systemic risk (Brunnermeier et al., 2009; IMF, 2018; NTSA, 2011). South Africa's framework for regulating financial-sector entities is generally strong (IMF, 2022e), but exposure to systemic risk is nevertheless high (IMF, 2022c, e).

1.2 Insurers are generally regarded as unlikely to contribute as much to systemic risk as their banking counterparts, largely on the basis that insurers do not engage in peer-to-peer transactions to the same extent as banks (refer to the summary of the literature in Section 2). The potential for insurers to be systemically risky entities is nevertheless not immaterial (Baluch et al., 2011; Bierth et al., 2019; Cummins & Weiss, 2014; Eling & Pankoke, 2016; Schwarcz & Schwarcz, 2014, for example, refer to Section 2.3) and should be guarded against by regulators.

1.3 The South African Reserve Bank includes observations on the potential contribution by the insurance sector in its reviews of financial stability (see SARB, 2021b, 2022, for example). In the United Kingdom, a spike in government bond yields led to severe liquidity pressure on liability-driven investment arrangements, some of which were managed by insurers, triggering Bank of England intervention (Chen & Kemp, 2023; Financial Stability Committee, 2022; Pinter, 2023). These events, following shortly after the generally positive views of the IMF regarding the capacity of the insurance sector to absorb even large increases to interest rates (IMF, 2022a), serve to illuminate the systemic significance of insurance markets, as part of the wider non-bank financial sector.

1.4 This paper proposes an approach to identifying the sources of systemic risk arising in the insurance sector. The approach is based on a classification system that is developed from a survey of the available literature and examination of the corresponding frameworks proposed by others. It contributes to the literature on systemic risk attributable to insurers by proposing a practical approach to identifying the sources of such risk arising in insurers across the market. It applies this approach to the South African insurance environment by considering those sources of risk that have been acknowledged by several insurers and recommending regulatory action to detect the possibility of other sources of systemic risk across the framework.

1.5 Several quantitative approaches to assessing levels of systemic risk have been developed (see Section 3.4, in particular the literature summaries by Silva et al. (2017) and Ellis et al. (2022)). Practical constraints limit the effectiveness with which such approaches may be applied to insurers (refer to the considerations set out in Section 4.4). This study aims to provide pragmatic approaches to insurance regulators to mitigate these constraints.

Improving the effectiveness of the available qualitative approaches for identifying the sources of systemic risk attributable to insurers contributes to a more robust understanding of the nature of this risk that might be supported by such modelling.

1.6 Section 2 describes the objectives-based approach to financial-sector regulation and summarises the literature on the question of the insurer contribution to systemic risk. It also describes South Africa's insurance market. Section 3 sets out the methodology underpinning the research. It describes the development of the framework proposed for identifying and classifying the sources of systemic risk attributable to insurers. It also summarises the financial models available for detecting such risk quantitatively and considers the appropriateness of these models to meeting regulatory objectives. Section 4 summarises the results of the analysis. It demonstrates how this framework may be utilised by describing a survey of South Africa's insurers to identify the extent to which some of these sources of risk have been acknowledged already. Section 5 concludes, setting out thoughts on potential supporting research.

2. BACKGROUND

The discussion in this section provides a foundation to the analysis that follows. It describes the widely adopted position of financial-sector regulators that their approach should be directed by a set of regulatory objectives, one of which should be to mitigate the impacts of systemic risk. It then turns to the question of whether insurers contribute materially to systemic risk and how they might do so. The section closes with a description of South Africa's insurance market.

2.1 Objectives-based financial-sector regulation

2.1.1 Financial-sector regulation has been subject to significant development over the last two or three decades (Atack, 2009; Black, 2004; FSA, 2006, 2007; Llewellyn, 1999). Some of these changes have been stimulated by contemporary events such as the 2007–09 financial upheaval. The crisis drew considerable attention to the challenges of systemic risk and the inadequacy of the regulatory response to it (Grochulski & Morrison, 2014; OECD, 2010; Schwarcz, 2014).

2.1.2 Several regulators have adopted an objectives-based model to determine their priorities, for instance, those in Australia, the United Kingdom, Singapore and South Africa (APRA, 2014; FSA, 2007; MAS, 2015; NTSA, 2011). Under this approach, regulators identify the objectives of their intervention in financial markets and determine the actions considered most effective at meeting these objectives, taking into account the risks that regulation seeks to mitigate (Armour et al., 2016; Baldwin & Black, 2016; Black & Baldwin, 2010, 2012; Knot, 2014; Michael et al., 2010; Sinha, 2012).¹

2.1.3 The success or failure of this approach could prove highly significant to the financial sectors and wider economies of the countries served by such regulations. Financial

1. Refer to Rusconi (2020) for a summary of the primary reasons for employing an objectives-based regulatory framework.

markets are critically important to the economies they serve (Merton, 1995; OECD, 2010; World Bank, 2012), but they are also characteristically complex, fragile and changeable (ADB, 2017; Erskine, 2014; European Central Bank, 2012; Schmukler, 2004; Tagoe, 2016).

2.2 Defining systemic risk

A well-established objective in many markets is the prevention or mitigation of systemic risk (Brunnermeier et al., 2009; Carvajal et al., 2009; Grochulski & Morrison, 2014; IMF, 2013, 2014b, 2018). Achieving this objective calls for a strong understanding of the nature of the risk, its origins and its channels of propagation. It also requires sound comprehension of the way alternative forms of intervention might prevent the occurrence of this risk or mitigate its effects (Baldwin & Black, 2016; EIOPA, 2017, 2019a,b; OECD, 2010), helping regulators to understand which of their available actions might best meet their stated objectives.

Since one of the objectives of financial-sector regulation is to mitigate the impacts of systemic risk, defining this risk unambiguously is important. Several researchers have grappled with this problem, with limited success (Claessens, 2015; Eling & Pankoke, 2016; European Central Bank, 2010; Galati & Moessner, 2014; Hansen, 2013). A joint statement of the International Monetary Fund, Bank for International Settlements and Financial Stability Board to the G20 (IMF et al., 2009: 2) describes systemic risk as “a risk of disruption to financial services that is (i) caused by an impairment of all or parts of the financial system and (ii) has the potential to have serious negative consequences for the real economy.”

The following characteristics might be considered to represent broad consensus on the attributes of systemic risk (Acharya et al., 2017; Bisias et al., 2012; Cummins & Weiss, 2014; De Bandt & Hartmann, 2000; Eling & Pankoke, 2016; Georg, 2011; Harrington, 2009; Kessler, 2014; Nier et al., 2007; Safa et al., 2013; Weiß & Mühlhnickel, 2014): (1) preconditions of widespread market connectedness or interdependence, (2) substantial loss of confidence leading to economic losses, (3) extensive adverse impacts on financial entities and (4) market failure, often resulting in considerable adverse impact on the wider economy. Underpinning this paper is the view that regulators should strive to understand the dynamics of systemic risk in their markets and to enhance their ability to detect any warning signs that such risk may be rising.

2.3 Insurer contribution to systemic risk

2.3.1 The discussion turns next to the question of whether insurers, individually or collectively, contribute substantially to systemic risk.²

2.3.2 It is widely accepted that the contribution to systemic risk by insurers is generally weaker than the corresponding contribution by banks. The primary reasons for this are that insurers are less likely to provide and demand financial support from peers and insurers

2. Eling & Pankoke (2016) provide a thorough meta-analysis of the literature concerned with the contribution of insurers to systemic risk. Refer to Rusconi (2020) for a more detailed consideration of the contribution by insurers to systemic risk with particular application to South Africa.

typically retain on their balance sheets, hence transparently report, potentially risky financial activities (Baluch et al., 2011; Bierth et al., 2019; Billio et al., 2012; Bobtcheff et al., 2019; Eling & Pankoke, 2016; Kaserer & Klein, 2019; Kessler, 2014; Van Lelyveld et al., 2019).

2.3.3 Several other reasons for this position may be added to these. Insurers are generally well regulated (Cummins & Weiss, 2014). Claims are typically dependent on random events rather than on customer behaviour (Baluch et al., 2011; Cummins & Weiss, 2014; Kessler, 2014) and are payable over an extended period (Cummins & Weiss, 2014; IAIS, 2011; Kessler, 2014; Trichet, 2005). Premiums are largely payable in advance (Cummins & Weiss, 2014; Kessler, 2014; Trichet, 2005). Fees on lapses mitigate the risk of customer runs attributable to deteriorating confidence (Kessler, 2014). Product substitutability is generally high (Cummins & Weiss, 2013, 2014), business lines are separable and entity risks are typically idiosyncratic and uncorrelated (IAIS, 2011). Inter-connectedness between insurers is low (Baluch et al., 2011; Cummins & Weiss, 2013; Grace et al., 2013; IAIS, 2011; Kessler, 2014; Trichet, 2005), risk transfer is typically hierarchical, not peer-based (Baluch et al., 2011; Besar et al., 2011; IAIS, 2011), external funding is available (Berry-Stölzle et al., 2014) and reinsurance bankruptcy can be absorbed (Park & Xie, 2014; Van Lelyveld et al., 2019). Insurer wind-up is generally a lengthy, orderly process (IAIS, 2009, 2010) because the liabilities in specific business lines can be isolated for sale or running down (IAIS, 2011). Finally, the insurance industry is more robust to economic adversity, in contrast to the corresponding experience of the banking industry (Berry-Stölzle et al., 2014).

2.3.4 Notwithstanding these mitigating factors, the contribution to systemic risk by insurers is potentially significant (Baluch et al., 2011; Bierth et al., 2019; Cummins & Weiss, 2014; Schwarcz & Schwarcz, 2014) and should not be ignored. This contribution, furthermore, may be exacerbated by the attributes, business activities or behaviour of insurers (Baluch et al., 2011; Bobtcheff et al., 2019; Cummins & Weiss, 2014; EIOPA, 2017; Eling & Pankoke, 2016; Koijen & Yogo, 2017; Weiß & Mühlhnickel, 2014). These attributes, activities and behaviour represent the focus of this research, considering both the literature (Section 3) and evidence from the market (Section 4).

2.3.5 Furthermore, even if insurers do not originate systemic risk, they may propagate or magnify it, typically through collective reactions or decisions (EIOPA, 2017; IAIS, 2019). These might include the sale of assets that intensify market movements and contribute to volatility, transfers of losses to other market participants or the interruption of a critical function, in this case the insurance service, in the process exacerbating distress elsewhere in the economy (IAIS, 2019).

2.3.6 Insurers that form part of a financial group are generally more likely to contribute to systemic risk, particularly if one or more banks are also members of the group (Baluch et al., 2011; Hauton & Héam, 2015). Insurers are also impacted by their customers. They may contribute to systemic risk through the behaviour of policyholders, which is linked to the state of the economy or the condition of other financial institutions (Barsotti et al., 2016; Klein, 2012; Russell et al., 2013).

2.3.7 For the purpose of managing systemic risk, regulators must take care not to depend on even soundly-established micro-prudential regulatory methods. These methods

focus considerable attention on idiosyncratic risk at regulated entities, but may contribute to behavioural herding that could paradoxically increase systemic risk (Al-Darwish et al., 2011; Floreani, 2013; Rae et al., 2017; Swarup, 2012). Furthermore, the pursuit of diversification at entity level, encouraged by micro-prudential regulatory methods, could contribute to systemic risk (Acharya, 2009; Allen & Carletti, 2006; Checkley, 2009; Ibragimov et al., 2011; Wagner, 2010).

2.3.8 In summary, though insurance is typically less systemically risky than banking, regulators should be aware that insurers can indeed contribute to systemic risk. They may originate systemic risk through their attributes or activities. They may contribute to the propagation of systemic risk through their collective reactions to adverse events. They may exacerbate systemic risk through their links to other financial-sector entities, particularly banks.

2.3.9 Finally, scope remains for quantitative assessment of the respective contributions to systemic risk by individual entities (Acharya et al., 2012, 2017; Adams et al., 2014; Adrian & Brunnermeier, 2016; Brownlees & Engle, 2017; Bui et al., 2017; Fong et al., 2009; Gauthier et al., 2012; Giglio, 2016; Hautsch et al., 2015; Huang et al., 2012; Sedunov, 2016; Zhang et al., 2015), taking care to understand the drivers and transmission channels of systemic risk (EIOPA, 2017). However, attention should be given to the effectiveness with which the methods used to assess banks could be applied to insurers. This also forms part of the assessment described in this paper (see Section 3.4 and its application in Section 4.4).

2.4 South Africa's insurance market

2.4.1 South Africa's financial sector is large and sophisticated (IMF, 2014a, 2022e) with significant assets assessed against gross domestic product (IMF, 2014a). It is also complex, however, and concentrated, with high levels of inter-connectedness between banks and other financial institutions (IMF, 2008, 2014a, 2022e). Prudential regulation of financial-sector entities falls under the responsibility of the Prudential Authority, a division of the South African Reserve Bank (SARB). The Prudential Authority acknowledges explicitly its responsibility to identify and mitigate potential contributions to systemic risk, as part of the SARB and in partnership with the market-conduct regulator, the Financial Sector Conduct Authority (Prudential Authority, 2021).

2.4.2 The insurance sector is similarly large and complex, but it is also competitive, with a diverse range of business models (IMF, 2022c). Assets in life insurers (also termed long-term insurers) amount to some two-thirds of annual gross domestic product (Prudential Authority, 2019; Rusconi, 2020) and the non-life (short-term) insurance market is large and competitive (KPMG, 2022; Rusconi, 2020). The insurance industry is generally well regulated, implementing several significant recent enhancements (IMF, 2022c,e), has high levels of solvency (IMF, 2022c) and weathered the storm of the COVID pandemic relatively well (IMF, 2022e).

2.4.3 International observers have nevertheless noted several systemic risks related to South Africa's insurance sector. Among them are: considerable inter-connectedness of financial entities (IMF, 2022c), dependence by banks on the liquidity provided by non-

bank institutions (IMF, 2022e), large equity holdings by insurers (IMF, 2022c), high rates of lapses and surrenders by policyholders (IMF, 2022c), high dependence on the accuracy of the assumptions underlying the modelling of idiosyncratic risk in insurers (IMF, 2022c) and, together with other financial institutions, relatively high holdings of sovereign debt (IMF, 2022d). The IMF notes as well concerns regarding inadequate transparency of the Financial Stability Committee (IMF, 2022e, f) and the potentially adverse impacts of systemic governance weaknesses uncovered in the public- and private sectors (IMF, 2022b).

3. DESCRIPTIVE FRAMEWORK

3.1 Introductory comment

3.1.1 The literature exploring the nature of systemic risk and the manner of its propagation (see Section 2) suggests that the contribution of banks to systemic risk is generally greater than that of insurers. By the nature of the financial interactions between entities, the banking system both propagates and absorbs risk. Insurers typically do not operate in this manner. They absorb risk from their customers, but they redistribute this risk in a hierarchical structure, commonly through reinsurers. They are required to hold capital that is more than sufficient to back this risk and they typically retain all of their risk on their balance sheets.

3.1.2 The insurer contribution to systemic risk, however, is not immaterial, as summarised in Section 2 and discussed in more detail in this section. As regulated entities do not have the same economic incentives to mitigate externalities as they do to manage the risks that would impact their businesses directly (Schwarcz, 2008), regulators have the responsibility to mitigate systemic risk arising from these entities. In order to do this, they should seek to understand the nature of the contribution by insurers to systemic risk, through their attributes, business activities or behaviour, in the process identifying and mitigating this contribution to systemic risk. This is the subject of this article.

3.1.3 A survey of the literature exploring the contribution of insurers to systemic risk was undertaken. This utilised available literature reviews (notably (Cummins & Weiss, 2014; Eling & Pankoke, 2016), but original sources were scrutinised to ensure a sound understanding of the identified risk. The primary difficulty encountered was making sense of these risks by classifying them in a coherent form. The discussion that follows describes efforts to understand qualitatively the nature of this contribution and considers existing approaches to classifying these risks. It then proposes an alternative system of classification that could enhance the effectiveness by regulators of the management of systemic risk originating at or propagated by insurers. The final part of this section describes the corresponding quantitative methods available for assessing these risks and considers some of the difficulties of these methods.

3.2 Qualitative analysis: existing models

3.2.1 The European Insurance and Occupational Pensions Authority (EIOPA, 2017) suggests that systemic risk events and their impacts should be considered in two broad ways. Systemic risk may be introduced to markets directly, typically because of the failure of a significant insurer or group of insurers. This may be referred to as an entity-based source.

Alternatively, it may be indirect, activity-based or behaviour-based, under which the risks triggered by an outside set of events are propagated through the system by insurers either through their activities or through their reaction to events or the actions of others.

3.2.2 Entity-based risks are managed through existing micro-prudential approaches that are designed to identify and mitigate weaknesses in the risk-management systems of individual insurers. Several researchers have questioned the effectiveness of existing largely micro-prudential approaches for identifying systemic risks, in some cases arguing that these approaches stimulate herding behaviour that magnifies systemic risk (Al-Darwish et al., 2011; Floreani, 2013; Rae et al., 2017; Swarup, 2012). This, however, is only one part of the EIOPA (2017) approach.

3.2.3 Examples of indirect activity-based sources identified by EIOPA (2017) include financial guarantees to customers, securities lending and derivative trading not concerned with hedging risk. Widespread use of strategies such as these should be a signal to regulators of elevated levels of systemic risk. Behaviour-based sources of risk under the EIOPA (2017) framework include (1) collective behaviour, like fire sales or herding, that may sharpen movements in market prices, (2) imprudent risk-taking or concentration of assets or liabilities, and (3) inadequate provisioning or under-pricing, typically under pressure from competitors. Adding to systemic tendency, these behaviours may be linked to market conditions like elevated competition, a search for yield or other asset-side herding behaviour, and moral hazard problems such as the too-big-to-fail risk.

3.2.4 The EIOPA (2017) model focuses not just on the sources of systemic risk, but the channels of transmission. These channels serve to amplify the propagation of systemic risk through financial markets. Such channels include linkages to banks and other financial institutions, asset liquidation risks and the use of bank-like products such as investment guarantees and options embedded in insurance products.

3.2.5 An effort was made to allocate all of the insurance-related risks identified in the literature to the EIOPA framework by identifying a type (entity, activity or behaviour) and nature (driver or transmitter). This proved difficult. Some risks impact insurers but originate outside of the insurance industry. Climate change, which impacts asset prices and insurance liabilities, is an example of such a risk. These risks could be excluded from the framework. Alternatively, to capture risks like this, the EIOPA framework could be modified to include, under the type, an impact, and, under the nature, a contributor. In other cases, choosing the most appropriate type or nature was difficult. Though a mapping of all of the risks identified in the literature (refer to Table 3 in Appendix B) to the modified EIOPA framework was completed, the consistency and reliability of the approach was considered unsatisfactory.

3.2.6 The International Association of Insurance Supervisors (IAIS) utilises a similar model, considering the origination and propagation of risks separately (IAIS, 2019). It identifies the primary sources of systemic risk in the insurance industry and the channels through which this risk may be transmitted to the wider economy. The most significant sources noted by the IAIS are (1) liquidity risk, (2) exposure to economic factors and to counterparties and (3) the effects of limited substitutability of essential products or services of one or more insurers. The transmission channels considered by the IAIS include (1) depressed

asset values resulting from fire sales, (2) economic impacts, through direct holdings in other financial entities or correlated experience with other institutions and (3) the interruption of critical functions.

3.2.7 An attempt was made to allocate each of the risks identified in the literature to the categories proposed by the IAIS, but this also proved challenging. In this case, the main problem experienced was that the IAIS categories are designed to incorporate the most significant systemic risks originated in or transmitted through the insurance industry. This made it inappropriate for the purpose of allocating a complete set of risks to these categories as several of the identified risks did not suit any of the available categories.

3.2.8 In view of the difficulties in allocating the identified risks to the categories proposed by either EIOPA or IAIS, an alternative classification system was developed.

3.3 Qualitative analysis: identifying and classifying insurance risks

The discussion that follows describes efforts to identify and classify the sources of systemic risk arising in or propagated by the insurance industry. This is undertaken through (1) a review of the literature to identify such sources and (2) an approach to classifying them into categories that would assist in the process of identifying any additional sources of or contributors to systemic risk.

3.3.1 OVERALL APPROACH

3.3.1.1 Classification takes place in two stages. The first of these results from a survey of the literature and results in a broad set of categories. The output of this approach is set out in Table 3 in Appendix B. The second represents a more concise categorisation which is used to organise risks identified in annual reports by South African insurers. This is described in the next part of the paper, Section 4.

3.3.1.2 In the assessment of the sources of systemic risk attributable to insurers, no distinction is made between origination and transmission, primarily because of the overlap between the factors respectively impacting origination and transmission. Furthermore, no attempt is made to prioritise these factors. The intention, rather, is to assist the insurance regulator by providing a framework for identifying such factors. With this in mind, the approach aims to be collectively exhaustive, by exploring possibilities across as wide a front as possible, and mutually exclusive, by allocating factors to distinct categories.

3.3.2 SOURCES UTILISED

3.3.2.1 The sources considered include academic literature and publications by regulators, like the SARB, or regulatory umbrella organisations, such as the IAIS. Sources of systemic risk identified by international or regional bodies like the IAIS or EIOPA are considered sufficiently broad for general application, but locally identified risks should be reviewed as part of a study of country-specific sources of systemic risk. This explains the inclusion of sources identified by the SARB. In most cases, these add descriptive detail to risks already noted in the literature without materially adding to the list. They are also typically mirrored by the corresponding sources of risk identified by insurers, as described in Section 4.

3.3.2.2 Meta-analysis is also utilised, referring to the corresponding literature reviews of authors such as Eling & Pankoke (2016) and Cummins & Weiss (2014). All references to the potential sources of systemic risk attributable to insurers, or factors exacerbating the transmission of systemic risk are noted. Efforts to evaluate the significance of a risk are not captured on the basis of the subjectivity of approach. For the same reason, the frequency with which risks are mentioned is not recorded, the main difficulty in this case being the variations in wording that make it difficult to establish whether different risks are identified or the same risk repeated.

3.3.3 APPROACH TO CLASSIFYING SYSTEMIC RISKS

3.3.3.1 As described in Section 3.2, difficulties were experienced in arranging and classifying the risks identified in the literature using available classification models and it was considered better to develop an alternative approach, with typical regulator approaches to identifying risks in mind. The approach proposed aims to assist regulators by aligning with existing methods for managing and mitigating insurance risk, categorising these risks first by balance sheet sector and then by the type of risk.

3.3.3.2 There are disadvantages to developing an approach similar to existing methods, the most important of which is that these methods are typically developed for micro-prudential purposes. Concerns are expressed by several researchers that the tendency of existing regulatory approaches to focus on idiosyncratic insurer-specific risk, not systemic risk, can exacerbate problems of systemic risk (Al-Darwish et al., 2011; Floreani, 2013; Ibragimov et al., 2011; Rae et al., 2017; Swarup, 2012; Wagner, 2010). This is mitigated by limiting the risks included in the framework to those identified as potentially systemic by credible sources in the literature. Significant overlap of these risks with the corresponding set of idiosyncratic risks is nevertheless likely, as many risks with potentially systemic attributes are also specific to individual insurers and could be identified and mitigated by these insurers.

3.3.3.3 The advantage of the proposed approach is that it is practical, fitting in with the existing framework and assisting regulators to extend that framework to identify and mitigate risks that may be systemic in their impacts.

3.3.4 CATEGORIES SELECTED

3.3.4.1 Risk categories are chosen on two levels: that part of the balance sheet most impacted by the risk and the broad form that the risk takes. Under the first of these, five alternatives are used. These are assets, liabilities, asset-liability management (ALM), solvency and a general category. The first two are used respectively to classify risks that operate primarily to affect the assets or liabilities of an insurer. The investment of assets and its impact on investment returns is an example of the first type and concentration of insured risks of the second. The ALM category is used for risks that affect the balance between assets and liabilities. For example, an excessive reliance on short-term funding in the context of long-term liabilities can introduce or exacerbate a mismatch of assets to liabilities. Solvency is used to capture risks that most directly impact the financial viability of the insurer. The

general category is used to capture risks that do not readily fall into other categories, typically covering risks of a strategic nature.

3.3.4.2 The second level of risk categories considers the broad type of risk: concentration of risk, a mismatch of the risk to its mitigation strategy, poor quality in product or investment, strategic risks, operational risks and general risks that do not fall into another category.

3.3.4.3 This approach aims to achieve objectives of collective exhaustion and mutual exclusivity most effectively, but it is affected by subjectivity. The meaning of researchers in characterising a risk could be misinterpreted. Two writers referring to the same risk may use different words, or the same terminology may be applied to risks that are actually distinct in their attributes. Subtle differences in wording can lead to misinterpretation regarding the nature of a risk or its application to different parts of a balance sheet. Some writers describe a risk in broad terms and others apply it more precisely to a specific area.

3.3.4.4 Consider the example of the substitutability of products, that is the breadth with which a particular offering is available across the market. This is identified by some writers in general terms (Cummins & Weiss, 2014; IAIS, 2018), while others note the impact of poor substitutability on industry capacity (IAIS, 2011) or consider the issue in specific classes of business (IAIS, 2019). It is at least clear that this is a risk concerned with concentration of liabilities. In other instances, it is not obvious whether a risk is more concerned with assets, in the case of structured securities, say, or ALM. For example, risks related to embedded investment guarantees in long-term insurance products may be allocated to liabilities, ALM or solvency. The broad approach employed in instances of doubt is to allocate risks first to assets or liabilities, then to ALM and then to solvency or to general risks.

3.3.4.5 Notwithstanding these concerns, the framework is regarded as helpful to regulators as an approach to categorise risks and to find areas of risk that have not yet been identified. Not all combinations of the categories used at the two levels are populated with identified risks, but these combinations could be used by regulators to identify possibilities not hitherto considered.

3.3.5 ALLOCATING RISKS TO CATEGORIES

3.3.5.1 Classification is undertaken in two stages. The first stage aims for collective exhaustion at the risk of some overlap or confusion of categories. This is used to classify the risks attributable to insurers that are identified in the literature. The second targets mutual exclusion by limiting the possibility of incorrectly allocating the risks identified by insurers. This is used to assess the risks reported by insurers themselves.

3.3.5.2 First, examples identified in the literature are classified broadly, keeping separate risks that may have distinct attributes. This potentially overstates the number of distinct categories of risk, but it allows others to interpret these categories as they wish, perhaps consolidating them or reorganising them to suit their purposes. This information is summarised in Table 3 in Appendix B.

3.3.5.3 Second, categories that appear similar are consolidated for the purposes of categorising risks identified by South African insurers, the results of which are shown in

Figure 1 and discussed in Section 4. This consolidation makes it easier to allocate these risks on a consistent basis. This process is also prone to subjectivity, as judgement is required on appropriate consolidation of the categories identified in the literature. The number of categories, 50 in total, is small enough to facilitate reasonable classification of risks identified through the market survey, but sufficiently large to distinguish appropriately between these risks and hence between the corresponding strategies to mitigate them.

3.3.5.4 The process of classifying risks and consolidating them into a more concise set of categories was completed prior to considering the evidence for each of the identified risk types, described in Section 4.

3.4 Quantitative analysis

3.4.1 Significant research has been undertaken to quantify the impacts of poor market conditions on individual entities and, in turn, the extent to which the collapse of individual companies might affect their peers and the broader market. Such work is hampered by the absence of consensus on what constitutes systemic risk (see Section 2.2) but it does encourage the use of a wide range of approaches, helpfully assessed and classified by Silva et al. (2017) and Ellis et al. (2022).

3.4.2 A summary of several studies of quantitative methods for assessing systemic risk is provided in Table 4 in Appendix B, drawing on the classification system proposed by Ellis et al. (2022). Measures of solvency include SRISK, the capital shortfall of an entity conditional on a crisis (Acharya et al., 2012; Brownlees & Engle, 2017) and Delta CoVaR, the marginal change in the value-at-risk of the system conditional on the distress of an entity (Adams et al., 2014; Adrian & Brunnermeier, 2016). While SRISK explores the possibility of market impacts on an entity and Delta CoVaR the corresponding impacts that an entity may have on the market, not all methods seek evidence of direction of effect. Alternative approaches include models of joint probabilities of default (Segoviano & Goodhart, 2009), Granger causality studies (Billio et al., 2012) and a variety of network models (Hautsch et al., 2015; Lee, 2013; Martinez-Jaramillo et al., 2015; Poledna et al., 2015).

3.4.3 The methods also have different data requirements. With the exception of Lee (2013), all of the studies listed in Table 4 utilise quoted market data, either stock returns or credit default swap (CDS) prices. Several of them also use accounting information, which is typically available at significantly lower frequency than the market data, calling for a blended approach to data from different sources. Refer to Adrian & Brunnermeier (2016) for a thorough explanation of the challenges involved.

3.4.4 On the whole, not a great deal of attention has been given to quantitative studies of systemic risk involving insurers. Exceptions to this include Weiß & Mühlnickel (2014), who report evidence that insurers materially contributed to instability of the financial system in the 2007–09 crisis, and Leukes & Odei-Mensah (2019), who include insurers alongside other financial-market entities in their study of systemic risk in South Africa.

3.4.5 While the continued use of such modelling in the insurance sphere is encouraged, its challenges should not be understated. First, market prices are not necessarily representative of the insurer. This would be the case where the group holding company rather

than the insurer itself is listed on the stock exchange. Second, not all countries have sufficient depth of CDS markets to enable these methods to be used with reliability: South Africa suffers this difficulty. Third, book values are typically available infrequently and are often delayed.³ Fourth, some methods call for comparison of a single entity with the market as a whole. Data challenges are often particularly acute for smaller entities. Though they do not contribute a great deal to aggregate market figures, these entities often bring unusual features to the market, so it can be difficult to claim that the market is adequately represented if smaller entities are not included in the available data. Both the market and accounting data of these entities are likely to be more difficult to obtain with accuracy than for their larger counterparts.

3.4.6 While some of these problems could apply to all financial-sector entities, they could be particularly acute for insurers. In South Africa, for example, while monthly bank accounting figures are centrally published in standard format with a delay of a few weeks, no such equivalent information is available on insurers. This means that information would need to be manually extracted from published reports, which are available quarterly at best and may be subject to inconsistency of definition and interpretation.⁴

3.4.7 The appropriateness of quantitative methods to analysing the contribution of South Africa's insurance industry to systemic risk is considered in Section 4.4, the last part of the discussion that follows.

4. APPLICATION TO SOUTH AFRICAN INSURERS

The discussion turns now to the application of the method of classifying insurance-related systemic risk to South Africa's marketplace, supported by the summary of the market set out in Section 2.4. This starts with a description of the analytical approach. It is followed by a discussion of the findings and consideration of the regulatory methodology that may be utilised in response to poorly-reported risks. The discussion closes with a reflection of the potential for quantitative methods in this environment.

4.1 Analytical approach

4.1.1 Section 3.3 describes the process of consolidating the broad system for classifying the sources of systemic risk attributable to insurers into a more manageable set of risks arranged into two types of categories. The first of these is that part of the balance sheet

3 The authors recently conducted an assessment of the relationship between the adverse experience of South African banks and the market as a whole. Monthly accounting data was used and quantile regression methods were employed, in line with the Delta CoVaR method of Adrian & Brunnermeier (2016), but using the accounting data only, not the market data in addition. Detecting stable patterns in the tails of the distribution on the basis of monthly banking data proved challenging.

4 In such instances, the regulatory authority typically has information of better quality than is publicly available. The Prudential Authority requires all registered insurers to submit returns on a standard format, which facilitates the extraction and analysis of industry data. This was required monthly during the economic difficulties associated with the COVID pandemic in 2020 and 2021, but the frequency with which these must be submitted has since reverted to quarterly.

most affected by the risk. The second is the broad form that the risk takes. The discussion that follows explains how evidence for the existence of each of these risks may be identified from within the insurance industry.

4.1.2 Entities quoted on the Johannesburg Stock Exchange publish annual reports meeting listing requirements. These reports include a description of the most significant risks that the entities are exposed to. In the interest of transparency, some companies issue several reports covering the listed entity and its subsidiaries. In some instances, unlisted entities publish similarly comprehensive reports. The analysis summarised in this discussion and in Figure 1 covers the last five years' reports of the seven financial groups that include the five largest life insurers by assets (Deloitte, 2022; Prudential Authority, 2022a) and the five most significant non-life insurers by premium volume (KPMG, 2022; Prudential Authority, 2022c). The value of assets of these groups (Deloitte, 2022; Hollard, 2021a; Outsurance, 2021) amounts to some 89 percent of industry assets (Prudential Authority, 2022b).⁵ The groups included in this analysis are, in alphabetical order, Discovery, Hollard, Liberty, Momentum Metropolitan, Old Mutual, Outsurance and Sanlam. Not all of the group entities issue separate reports for their life and non-life subsidiaries but, in most cases, the corresponding group reports identify risks relevant to these subsidiaries. Some 78 reports are included in the study, listed in Appendix A. Though all the annual reports and financial statements issued in the last five years were studied, in several cases the risks noted in these reports do not vary significantly from year to year.

4.1.3 Figure 1 maps the risks reported by South African insurers to the framework of systemic risks described in Section 3. Each of the risks identified in published reports is allocated to one of the categories. The reported or implied significance of each risk is not captured, either in terms of its likelihood or potential financial impact. There were several reasons for this, the most important of which is that the reports typically do not disclose this information. Even if some of them did, it is not considered possible to capture this data on a consistent, objective basis. Multiple mentions of the same risk type are also not captured, whether these occur in a single report or repeatedly over several years, again on the basis that it is difficult to do so without introducing an element of subjectivity.

4.1.4 As noted in Section 3.3.3 significant overlap with idiosyncratic risks is expected. Insurers are more likely to be focused on idiosyncratic risks, for their own purposes, than their systemic counterparts. Allocating the identified risks to categories identified in the literature as potentially systemic, however, allows the regulator to map the potential for systemic risk using these reports as one source of information.

4.1.5 Other risks of subjectivity remain, notably in the interpretation of the text and allocation of the risk to the available categories. Some risks are also less likely to be disclosed by insurers, even if they exist. This may be because insurers are typically focused on idiosyncratic risks rather than those with systemic qualities or because the risks disclosed are those more likely to be of interest to readers of the report, among them the regulator. It may

5 Hollard and Outsurance assets are for June not December, but contribute a small proportion to the total. The sources are listed in Appendix A.

also reflect internal blind spots. Insurers are unlikely, for example, to identify and disclose economic exposure through speculative derivatives or risks associated with governance inadequacy. Both of these require an element of judgement and are difficult to describe dispassionately. Ambiguous disclosure could be detrimental. Transparent communication in matters such as these should nevertheless exist between the entity and the regulatory authority. This paper hopes to facilitate regulatory identification of such matters.

4.1.6 The resulting output (see Figure 1) is a scatter plot showing the extent to which risks falling into each of the categories are disclosed by insurers and their group holding companies in their financial reports. Summaries of the frequencies with which risks are reported that fall respectively into each balance sheet category and risk type are shown in Table 1 and Table 2 and discussed below.

4.2 Discussion of findings

4.2.1 The bottom rows of Tables 1 and 2 show the overall frequency with which risks falling into the identified sub-categories are reported for each type of company. This frequency, averaging 0.28 across all entities, is highest for holding companies (0.33), followed by long-term insurers (0.28) and short-term insurers (0.21). This is consistent with the expectation that holding companies have a broader perspective on risks that could be systemic in nature and that systemic risk is more likely to originate in or be propagated by long-term insurers than by their short-term counterparts (Park & Xie, 2014, for example).

TABLE 1. Insurer risk identification by balance sheet category

The table shows the frequency with which risks of each balance sheet category are reported in the annual financial statements and supporting published documents of entities of different type. ALM refers to asset-liability management.

	Holding companies	Long-term insurers	Short-term insurers	Average
Assets	0.45	0.19	0.16	0.28
Liabilities	0.33	0.35	0.23	0.30
ALM	0.38	0.31	0.25	0.32
Solvency	0.14	0.25	0.21	0.20
General	0.20	0.00	0.00	0.08
Average	0.33	0.28	0.21	0.28

4.2.2 Table 1 indicates that risks concerning the allocation of assets, which includes asset-liability management, and risks of a general nature are most frequently disclosed and managed at holding-company level, where strategic decisions are more likely than at the level of the subsidiary. In contrast, risks focused on insurance liabilities and on solvency are more frequently noted at the level of the insurance licence, where the attention to these issues is likely to be more acute. The differences between long-term and short-term insurers are greatest for those risks impacting liabilities, solvency and asset-liability

Balance sheet element	Risk type	Risk form		
Assets	Concentration	Economic, policy and governance impacts on assets		
		Impacts of climate change on asset values		
		Interconnected stock market performance		
		Investment in banks and the real economy or direct banking business		
	Quality	Counterparty exposures		
		Investment through unregulated subsidiaries		
		Non-traditional investment activities		
		Complex structured securities, CDSs and others		
		Liabilities	Concentration	Catastrophe risk
				Impacts on climate change on liabilities
Correlated product classes				
Limited substitutability and capacity: general				
Substitutability limitations: class-specific concerns				
Exposure to social issues and the broader economy				
Insurer concentration and interconnectedness				
Reinsurance with limited risk transfer				
Mismatch	Products with guarantees and embedded options			
	Savings and investment in long-term insurance			
Quality	Policyholder lapses and surrenders			
	Product complexity			
Strategic	Bank-like product design			
	Distribution through banks			
	Credit protection and economic exposure			
	Exposure to burden of disease and economic impacts			
	Exposure to fraudulent activity			
	Insurer provides critical function with few substitutes			
	Third-party asset management			
	Operational	Cyber risk		
ALM	Mismatch	Asset lending and associated liquidity risk		
		Liquidity risks attributable to constrained funding, asset volatility or derivative exposure		
		Reliance on short-term financing		
		High exposure to equity investments		
		Maturity mismatches		
	Quality	Economic exposure attributable to speculative derivatives		
		Counterparty exposure, particularly from reinsurance		
		Alternative risk transfer, banking, hedge fund and synthetic investments		
	Strategic	Property management risk		
		Business model risks and interconnectedness		
Solvency	Concentration	Non-core activities and unusual exposures		
		Insurance-linked securities		
		Risk exposures attributable to links with reinsurers		
	Mismatch	Losses tranfered to other participants		
		Leverage		
	Quality	Funding structures		
	Strategic	Unduly rapid growth		
	Operational	Inadequate pricing and provisioning		
		Operational liquidity risk and limited fungibility within groups		
		Policy and regulation not geared towards reducing systemic risk		
General	General	Panic run possible		

FIGURE 1. Systemic risks identified for large South African insurers

The figure (1) synthesises the risk forms identified in the literature and set out in Table 3, (2) indicates those risks reported by seven South African insurance groups and their subsidiaries and (3) summarises the proposed mitigation strategy for those reported with poor frequency (normal text) or not identified at all (bold text). Background to the analysis is available in Section 4. The numbers in the table denote the

SARB	Total	Grp	LTI	STI	Group A		B		C		D		E		F		G		Mitigation
					Grp	LTI	STI	Grp	LTI	STI	Grp	Grp	Grp	LTI	STI	STI			
	9	5	2	2															Scrutiny of impacts and potential concentration of risk Stress tests and capital buffers
	3	3																	
	1	1																	
	4	3	1																
	10	4	3	3															
	2	2																	Regulatory scrutiny and focus on group risk Regulatory analytics and detailed probes Analysis of derivative holdings and their purpose
	9	3	3	3															
	5	4		1															
	4		2	2															
	9	5	1	3															Concentration studies and care over barriers to entry Focused market-sector analysis
	2	1	1																
	2		1	1															
	6	3	3																
	5	1	4																
	8	3	4	1															Market conduct focus Product definition and control measures
	1		1																
	3	1	1	1															
	12	5	3	4															
	6	3	2	1															
	1		1																Focus on operational risk management Class-by-class identification of potential for concentration Minimum governance standards
	6	4	1	1															
	2	2																	
	9	3	3	3															
	13	5	4	4															
	2	2																	Standard regulatory reporting
	11	4	4	3															
	4	2	1	1															
	7	3	3	1															
	1	1																	
	1	1																	Occasional focus on strategic risk management Systematic disclosure framework covering assets and liabilities Identification and assessment Reinsurer solvency and analysis of concentration risks Assessment of inward reinsurance arrangements Microprudential tools and shock testing
	1	1																	
	1		1																
	3	1	1	1															
	1	1																	
	3		1	2															Scenario testing and focus on identified insurers
	8	2	3	3															
	2	2																	
	1	1																	
	9	5	1	3															Increasing regulatory focus on systemic risk Scenario testing and care over product design
	2	1	1																
	2		1	1															
	6	3	3																
	5	1	4																
	8	3	4	1															Market conduct focus Product definition and control measures
	1		1																
	3	1	1	1															
	12	5	3	4															
	6	3	2	1															
	1		1																Focus on operational risk management Class-by-class identification of potential for concentration Minimum governance standards
	6	4	1	1															
	2	2																	
	9	3	3	3															
	13	5	4	4															
	2	2																	Standard regulatory reporting
	11	4	4	3															
	4	2	1	1															
	7	3	3	1															
	1	1																	
	1	1																	Occasional focus on strategic risk management Systematic disclosure framework covering assets and liabilities Identification and assessment Reinsurer solvency and analysis of concentration risks Assessment of inward reinsurance arrangements Microprudential tools and shock testing
	1	1																	
	1		1																
	3	1	1	1															
	1	1																	
	3		1	2															Scenario testing and focus on identified insurers
	8	2	3	3															
	2	2																	
	1	1																	
	9	5	1	3															Increasing regulatory focus on systemic risk Scenario testing and care over product design
	2	1	1																
	2		1	1															
	6	3	3																
	5	1	4																

number of entities identifying each risk as applicable to them. Sources are as follows: ‘Grp’ indicates the group or holding company, ‘LTI’ a long-term insurer and ‘STI’ a short-term insurer. The reports assessed are listed in Section A of the Appendix. Not all entities publish group reports and only some of them have both long- and short-term insurers in the group.

management. This is consistent with the higher likelihood of a duration mismatch between assets and liabilities at long-term insurers than at their short-term counterparts.

4.2.3 Similar patterns are observed concerning the frequency with which risks are identified by category, shown in Table 2. Groups more frequently report on concentration-, strategic- and general risks than their insurance subsidiaries, consistent with the high-level perspective of these entities. Long-term insurers note risks of mismatching more often than their short-term counterparts, in line with the duration-based complexity of both their assets and their liabilities. Both holding companies and long-term insurers report risks of quality with relatively high frequency. These risks typically concern counterparty risks, alternative risk transfer, property management risk and product complexity. Short-term insurers identify operational risk more frequently than their long-term and holding-company counterparts. Though this is based on a sample cluster of risks, it is consistent with the generally higher operational intensity of short-term insurers and the competitiveness of their pricing in many product categories.

TABLE 2. Insurer risk identification by risk type
The table shows the frequency with which risks of each broad type are reported in the annual financial statements and supporting published documents of insurers and their holding companies.

	Holding companies	Long-term insurers	Short-term insurers	Average
Concentration	0.37	0.21	0.21	0.27
Mismatch	0.38	0.48	0.20	0.35
Quality	0.32	0.33	0.23	0.29
Strategic	0.24	0.18	0.15	0.19
Operational	0.40	0.42	0.50	0.44
General	0.20	0.00	0.00	0.08
Average	0.33	0.28	0.21	0.28

4.2.4 The discussion turns now to the frequency with which risks in each sub-category are reported (refer to the blue and green columns in Figure 1) and the overlap with those risks identified by the SARB in its financial stability reviews (refer to the column labelled ‘SARB’). Those risks most consistently noted by insurers include exposure to counterparties, including reinsurers, to stock market volatility and to risks concerned with uncertainty in social and economic conditions and government policy. Several insurers also identify catastrophe risk, lapses and surrenders by policyholders and liquidity risk as potentially significant contributors to adverse experience.

4.2.5 While some overlap of these risks with those noted by the SARB in its focus on systemic risk exists, such overlap is not particularly strong. The SARB, for example, has not identified counterparty risk or equity exposure as material systemic risks in its financial stability reports of the last few years, perhaps on the basis that it regards these

risks as broadly under control. Furthermore, some of the risks noted by the SARB have not been identified by insurers with high frequency. These include the impacts of climate change, insurer concentration and exposure to fraudulent activity. This may indicate that they are limited to pockets of insurers. It may instead illustrate the difference in perspective between the regulator, which is concerned about systemic risk, and the regulated entities that have a limited incentive to manage risks whose impacts could be widely felt but might not directly impact the entities themselves (Schwarcz, 2008). Climate change and insurer concentration are examples of such risks.

4.3 Risks infrequently reported by insurers

4.3.1 The focus of the discussion turns now to those risks of a systemic nature that are infrequently identified by insurers, or not at all. The possibility of bias in the source data is acknowledged. Insurers and their holding companies are unlikely to report risks judged likely to have little impact on their operations or financial positions, even if these risks have potential systemic effects. Their absence from the annual financial reports of the largest insurers and their holding companies cannot be construed either as poor identification by these entities or that the risk is not relevant to the South African environment.

4.3.2 No instances were found, for example, of insurers identifying the risks associated with investment through unregulated subsidiaries or any non-traditional investment activities. There are good reasons for this. In the first instance, if insurers were using unregulated subsidiaries to channel investment, the status of such entities as unregulated would most likely not be highlighted in annual reports. Insurers are required to submit detailed charts of group organisational structures to the regulator, however, facilitating the identification of such subsidiaries outside of the public domain. This is consistent with regulatory focus on group risk. In the second instance, the term ‘non-traditional’ is subjective. Several insurers disclose investment in derivative structures to match their liabilities. Whether this match is perfect or whether some of these derivative arrangements are motivated by the pursuit of return rather than the management of risk is difficult to determine but would also be expected to form part of regulatory scrutiny.

4.3.3 In each case of risk sub-categories with no reporting or sparse reporting by insurers, further analysis is warranted to determine the likelihood that the risk exists and the extent of its potential impact on the financial system. This is most appropriately carried out by the regulator, in discussion with the insurers. Brief thoughts regarding the approach to each of these risks are indicated in the right-most column of Figure 1, in bold text where no instances of the risk are reported. With reference to the examples mentioned in the previous paragraph, for instance, the regulator is in a strong position to scrutinise group structures and probe the investment activity of insurers, using standardised reporting information and supporting this with more detailed investigation where appropriate. These examples call for detailed analysis at insurer- or group level.

4.3.4 Some risks require investigation that is technically complex or must be carried out across the industry. A few examples are considered in the discussion that follows. Investigation of insurer concentration is relatively straightforward where it is limited to

the proportion of assets or premium income attributable to the largest insurers, but product substitutability concerns require a more nuanced and detailed understanding that may prove beyond the means of the analysis of the standardised annual or quarterly regulatory insurance returns. Investigation of reinsurance arrangements with limited transfer of risk, or product complexity or of bank-like products offered by insurers all require technical knowledge and judgement. Expertise in governance and risk management is required to assess the risks of inadequacy in leadership or the effectiveness with which board policies are drafted and implemented.

4.3.5 Different approaches may be required at group level, where the respective attributes of distinct types of entities in the group may be considered, along with the potential for a contribution to systemic risk arising from interaction between these entities. A useful start to this process could be to consider whether, for each of the risk sub-types listed in this framework, the potential for risk magnification may exist as a result of attributes of the group and its relationships.

4.3.6 Most of the interaction and correspondence between the regulator and the entities that it oversees is not in the public domain. The summarised findings of this interaction, however, are frequently published in order to enhance awareness and influence behaviour. The categories and sub-categories used in this study to describe the types of systemic risks that might originate at or be propagated by insurers are designed to assist regulators to identify and manage these risks and to publicise the extent to which it is doing so. It should link this explicitly to its regulatory objectives.

4.3.7 Through their micro-prudential oversight, regulators expect to have a strong understanding of the idiosyncratic risk profile of supervised entities. The approach proposed aims to assist regulators to convert this insight into an analysis of the potential for these risks to become systemic in nature. It is hoped that this framework would assist South Africa's Prudential Authority and regulators in other jurisdictions not only to identify and manage systemic risk in their insurance markets but also to plan their resourcing requirements. How they might respond to risks needs to be appropriate to the circumstances. Identified instances of systemic risk call for case-specific responses, some of which need to be coordinated across entities. Such interventions may range from requirements of entities to mitigate specified risks or improve solvency levels to industry-wide initiatives to raise organisational resilience to uncertainty.

4.4 Quantitative analysis in practice

4.4.1 Some of the models used to assess the contribution of banks and insurers to systemic risk are summarised in Section 3.4. The most significant limitations of these models and some of the challenges concerning the data that they require are also considered in that discussion.

4.4.2 Notwithstanding these limitations, ongoing quantitative analysis of the systemic risk indicators and the drivers of systemic risk should be undertaken. The regulatory authority is typically in the strongest position to model systemic risk on the basis that it has the best access to the information required to do so. Where such information is desirable,

but not currently available, consideration should be given to requesting regulated entities to submit this to the regulator. Where quarterly reports are submitted under the existing regulatory framework, for example, consideration should be given to the need for monthly information, possibly with backdated information to establish a history. For the purposes of this analysis, a significantly simplified version of the standard reporting template may be sufficient.

4.4.3 It is recommended that consideration be given to the appropriateness of several alternative models, such as Delta CoVaR, SRISK, Marginal Expected Shortfall and Systemic Expected Shortfall. Where alternative methods are possible, under each of these models, these should be actively investigated, preferably by constructing several of these alternatives and studying the reasons for differences in the results. Consideration of the detail underlying the models is likely to prove more helpful to an understanding of systemic risk than a blind acceptance of the outputs from just one model.

4.4.4 In time, the insights gained from this process could be shared with industry participants, with invitation to comment, potentially justifying the need for more frequent or more detailed information.

5. CONCLUDING COMMENTS

5.1 Identifying and mitigating instances of systemic risk in the financial sector are priorities for regulatory authorities around the world. It is broadly agreed that banking contributes to systemic risk by virtue of the inter-linkages between entities. The nature of the corresponding contribution by insurers is not as obvious. This article proposes a framework for classifying the sources of systemic risk attributable to insurers. The thorough approach to classification aims also to improve detection and identification of risk sources. It applies this framework to the insurance market in South Africa, in the process providing practical recommendations for consideration by all regulators.

5.2 While several approaches have been developed for assessing quantitatively the contribution to systemic risk by individual entities, practical constraints inhibit the application of quantitative methods to insurers, particularly in countries like South Africa with data limitations. Regulators are encouraged to explore the merit of these methods and to call for the data required to support this exploration. The framework presented herein aims to assist regulators to build a coherent understanding of the potential for systemic risk of various kinds arising from the insurers that fall under its responsibility, in turn contributing to efforts to develop supporting quantitative methods.

5.3 The discussion concludes with possibilities for further research. Possibilities for further exploration of a qualitative nature include the following. First, deeper engagement with insurers could be considered to understand their risk profiles in more detail. This might be conducted through structured interviews or an analysis of their management accounts or product ranges. Second, the risk sub-types defined in the literature and classified in two stages in this study could be more precisely defined, perhaps with the attributes of insurers

or their activities that regulators should look out for to identify evidence for each risk. Third, further study of insurance groups could be conducted in order to apply the methodology proposed in this paper to complex entities of various kinds. Fourth, cross-country studies could be considered that aim to identify systemic risks that are similar across jurisdictions or distinct to particular markets, in the process assisting in the development of appropriate responses to regulators. Finally, engagement with regulators might be considered, across countries or through regulatory associations, to gain insight into their perspective on the risks most commonly encountered and the most effective corresponding mitigating actions.

5.4 Several avenues could also be considered for further research of a quantitative nature. A detailed assessment of the alternative approaches that may be used for modelling in a particular country could be carried out. This could take into account the nature of the risks that characterise the insurance market in that country and the type and accuracy of data available. The models considered in this paper typically have several components. Consideration of the insights available from each of these components might be assessed and described.

5.5 The question of whether insurers might contribute to systemic risk is not a simple one. It is nevertheless a question that deserves the consideration of financial-sector regulators within the framework of their regulatory objectives. This paper aims to provide a practical framework within which regulators might identify and categorise the sources of systemic risk arising in insurers with a view to monitoring and mitigating such risk.

STATEMENTS AND DECLARATIONS

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors have no financial or non-financial interests directly or indirectly related to the work submitted for publication. The information utilised and generated during the study described in this paper is available from the corresponding author on request. Comments received from anonymous reviewers of the draft submitted to the *South African Actuarial Journal* are gratefully acknowledged.

REFERENCES

- Acharya, VV (2009). A theory of systemic risk and design of prudential bank regulation. In: *Journal of Financial Stability* 5, 224–55
- Acharya, VV, Biggs, J, Hanh, L, Richardson, M & Ryan, S (2011). Systemic risk and the regulation of insurance companies. In: *Regulating Wall Street – The Dodd-Frank Act and the New Architecture of Global Finance*. Ed. by Acharya, VV, Coley, TF, Richardson, M & Walter, I. Hoboken, NJ: John Wiley & Sons, 241–301
- Acharya, VV, Engle, RF & Richardson, M (2012). Capital shortfall: A new approach to ranking and regulating systemic risks. In: *American Economic Review* 102(3), 59–64
- Acharya, VV, Pedersen, LH, Philippon, T & Richardson, M (2010). *Measuring systemic risk*. Working Paper. Federal Reserve Bank of Cleveland
- Acharya, VV, Pedersen, LH, Philippon, T & Richardson, M (2017). Measuring systemic risk. In: *The Review of Financial Studies* 30(1), 2–47
- Acharya, VV & Richardson, M (2014). Is the insurance industry systemically risky? In: *Modernizing Insurance Regulation*. Ed. by Biggs, JH & Richardson, M. 1st ed. Hoboken, NJ: John Wiley & Sons, 151–79
- Adams, Z, Füss, R & Gropp, R (2014). Spillover effects among financial institutions: A state-dependent sensitivity Value-at-Risk approach. In: *Journal of Financial and Quantitative Analysis* 49(3), 575–98
- ADB (2017). *Asian Economic Integration Report*. Asian Development Bank
- Adrian, T & Brunnermeier, MK (2016). CoVaR. In: *American Economic Review* 106(7), 1705–41
- Aikman, D, Alessandri, P, Eklund, B, Gai, P, Kapadia, S, Martin, E, Mora, N, Sterne, G & Willison, M (2011). Funding liquidity risk in a quantitative model of systemic stability. In: *Financial Stability, Monetary Policy, and Central Banking*. Ed. by Alfaro, R. Vol. 15. Central Banking, Analysis, and Economic Policies Book Series. Central Bank of Chile. Chap. 12, 371–410
- Al-Darwish, A, Hafeman, M, Impavido, G, Kemp, M & O'Malley, P (2011). *Possible unintended consequences of Basel III and Solvency II*. Working Paper WP/11/187. International Monetary Fund
- Allen, F & Carletti, E (2006). Credit risk transfer and contagion. In: *Journal of Monetary Economics* 55, 89–111
- APRA (2014). Annual Report 2014. Australian Prudential Regulation Authority
- Armour, J, Awrey, D, Davies, P, Enriques, L, Gordon, JN, Mayer, C & Payne, J. (2016). The goals and strategies of financial regulation. In: *Principles of Financial Regulation*. Ed. by Armour, J et al. 51–79. doi: 10.1093/acprof:oso/9780198786474.003.0003
- Atack, J (2009). Financial innovation and crises: The view backwards from Northern Rock. In: *The Origins and Development of Financial Markets and Institutions: From the Seventeenth Century to the Present*. Ed. by Atack, J & Neal, L. Cambridge University Press
- Baldwin, R & Black, J (2016). Driving priorities in risk-based regulation: What's the problem? In: *Journal of Law and Society* 43(4), 565–95
- Baluch, F, Mutenga, S & Parsons, C (2011). Insurance, systemic risk and the financial crisis. In: *The Geneva Papers* 36, 126–63
- Baranoff, E (2012). An analysis of the AIG case: Understanding systemic risk and its relation to insurance. In: *Journal of Insurance Regulation; Kansas City* 31(1), 243–70

- Barsotti, F, Milhaud, X & Salhi, Y (2016). Lapse risk in life insurance: Correlation and contagion effects among policyholders' behaviors. In: *Insurance: Mathematics and Economics* 71, 317–31
- Berry-Stölzle, TR, Nini, GP & Wende, S (2014). External financing in the life insurance industry: Evidence from the financial crisis. In: *Journal of Risk and Insurance* 81(3), 529–62
- Besar, Systemic risk and the interconnectedness between banks and insurers: An econometric analysis. In: *Journal of Risk and Insurance* 81(3), 623–52
- Chen, R & Kemp, E (2023). *Lessons from the United Kingdom's Liability-Driven Investment (LDI) Crisis*. Selected Issues Paper SIP/2023/049. International Monetary Fund
- Claessens, S (2015). An overview of macroprudential policy tools. In: *Annual Review of Financial Economics* 7, 397–422
- Cummins, JD & MA Weiss (2009). Convergence of insurance and financial markets: Hybrid and securitized risk-transfer solutions. In: *Journal of Risk and Insurance* 76(3), 493–554
- (2013). *Systemic risk and regulation of the US insurance industry*. Working Paper. Temple University, Philadelphia
- (2014). Systemic risk and the US insurance sector. In: *Journal of Risk and Insurance* 81(3), 489–527
- De Bandt, O & Hartmann, P (2000). *Systemic risk: A survey*. Working Paper No. 35. European Central Bank
- Deloitte (2022). *Africa Insurance Outlook 2022: Navigating the insurance landscape*. Deloitte South Africa
- EIOPA (2017). *The interplay of financial intermediaries and its impact on monetary analysis*. European Insurance and Occupational Pensions Authority, Publications Office of the European Union
- (2019a). *2020 Review of Solvency II*. European Insurance and Occupational Pensions Authority, Publications Office of the European Union
- (2019b). *Consultation paper on the opinion on the 2020 review of Solvency II*. European Insurance and Occupational Pensions Authority, Publications Office of the European Union
- Eling, M & Pankoke, DA (2016). Systemic risk in the insurance sector: A review and directions for future research. In: *Risk Management and Insurance Review* 19(2), 249–84
- Ellis, S, Sharma, S & Brzeszczyński, J (2022). Systemic risk measures and regulatory challenges. In: *Journal of Financial Stability* 61, 100960
- Erskine, A (2014). *Regulating the Australian financial system. The funding Australia's future project*. Australian Centre for Financial Studies
- European Central Bank (2010). Macro-prudential policy objectives and tools. *Financial Stability Review*, 129–37
- (2012). The interplay of financial intermediaries and its impact on monetary analysis. *Monthly Bulletin*, 59–73
- Financial Stability Committee (2022). *Financial Stability Report: December 2022*. Bank of England.
- Floreani, A (2013). Risk measures and capital requirements: A critique of the Solvency II approach. In: *The Geneva Papers* 38, 189–212
- Fong, T, Fung, L, Lam, L & Yu, I-W (2009). *Measuring the interdependence of banks in Hong Kong*. Working Paper 19/2009. Hong Kong Monetary Authority

- FSA (2006). *A guide to market failure analysis and high level cost benefit analysis*. Financial Services Authority
- (2007). *Principles-based regulation: Focusing on the outcomes that matter*. Financial Services Authority
- Galati, G & Moessner, R (2014). *What do we know about the effects of macroprudential policy?* DNB Working Paper No. 440. DeNederlandscheBank
- Gauthier, C, Lehar, A & Souissi, M (2012). Macroprudential capital requirements and systemic risk. In: *Journal of Financial Intermediation* 21, 594–618
- Geneva Association (2010a). *An account of the Geneva Association's ongoing dialogue on systemic risk with regulators and policymakers*. Special Report of The Geneva Association Systemic Risk Working Group
- (2010b). *Systemic risk in insurance: An analysis of insurance and financial stability*. Special Report of The Geneva Association Systemic Risk Working Group
- (2011). *Variable annuities with guarantees and use of hedging*
- Georg, C (2011). *Basel III and systemic risk regulation – what way forward?* Working Papers on Global Financial Markets No. 17. Universität Jena und Universität Halle-Wittenberg
- Giglio, S (2016). *Credit default swap spreads and systemic financial risk*. Working Paper Series No. 15
- Grace, MF, Rauch, J & Wende, S (2013). *Systemic risk and interconnectedness in the financial industry: Implications on regulation of financial conglomerates*. Working Paper. Georgia State University, Atlanta
- Grochulski, B & Morrison, W (2014). *Understanding market failure in the 2007–08 Crisis*. Economic Brief 14-12. Federal Reserve Bank of Richmond
- Hansen, LP (2013). *Challenges in identifying and measuring systemic risk*. BFI Working Paper Series No. 2012-012. Becker Friedman Institute for Research in Economics, University of Chicago
- Harrington, SE (2009). The financial crisis, systemic risk, and the future of insurance regulation. In: *Journal of Risk and Insurance* 76(4), 785–819
- Hauton, G & Héam, J (2015). Interconnectedness of financial conglomerates. In: *Risk* 3, 139–63
- Hautsch, N, Schaumburg, J & Schienle, M (2015). Financial network systemic risk contributions. In: *Review of Finance* 19(2), 685–738
- Huang, X, Zhou, H & Zhu, H (2012). Systemic risk contributions. In: *Journal of Financial Services Research* 42, 55–83
- IAIS (2009). *Systemic risk and the insurance sector*. International Association of Insurance Supervisors
- (2010). *Position statement on key financial stability issues*. International Association of Insurance Supervisors
- (2011). *Insurance and financial stability*. International Association of Insurance Supervisors
- (2012a). *Globally systemically important insurers: Proposed assessment methodology*. International Association of Insurance Supervisors
- (2012b). *Reinsurance and Financial Stability*. International Association of Insurance Supervisors
- (2018). *Holistic framework for systemic risk in the insurance sector, public consultation document*. International Association of Insurance Supervisors
- (2019). *Holistic Framework for systemic risk in the insurance sector*. International Association of Insurance Supervisors

- Ibragimov, R, Jaffee, D & Walden, J (2011). Diversification disasters. In: *Journal of Financial Economics* 99, 333–48
- IMF (2008). *South Africa: Financial system stability assessment*. Country Report No. 08/349, including report on the observance of standards and codes on the following topic: Securities Regulation. International Monetary Fund
- (2009). *Global financial stability report: Responding to the financial crisis and measuring systemic risks*. International Monetary Fund
- (2013). *Key aspects of macroprudential policy*. International Monetary Fund
- (2014a). *South Africa financial system stability assessment*. Country Report No. 14/340. International Monetary Fund
- (2014b). *Staff guidance note on macroprudential policy*. International Monetary Fund
- (2018). *The IMF's annual macroprudential policy survey – objectives, design and country responses*. International Monetary Fund
- (2022a). *Detailed assessment of observance of insurance core principles issued by the International Association of Insurance Supervisors*. United Kingdom Country Report No. 22/109, Financial Sector Assessment Program. International Monetary Fund
- (2022b). *South Africa, 2021 Article IV Consultation – Press release; staff report; and statement by the Executive Director for South Africa*. Country Report No. 22/37. International Monetary Fund
- (2022c). *South Africa financial sector assessment program: Technical note on insurance sector – regulation and supervision*. Country Report No. 22/185. International Monetary Fund
- (2022d). *South Africa financial sector assessment program: Technical note on systemic risk oversight and macroprudential policy*. Country Report No. 22/186. International Monetary Fund
- (2022e). *South Africa financial system stability assessment*. Country Report No. 22/39. International Monetary Fund
- (2022f). *South Africa: Selected issues*. Country Report No. 22/38. International Monetary Fund
- IMF et al. (2009). *Guidance to assess the systemic importance of financial institutions, markets and instruments: Initial considerations, report to the G-20 Finance Ministers and Central Bank Governors*. International Monetary Fund, the Bank for International Settlements, and the Secretariat of the Financial Stability Board
- Jobst, AA (2014). Systemic risk in the insurance sector: A review of current assessment approaches. In: *The Geneva Papers* 39, 440–70
- Kaserer, C & Klein, C (2019). Systemic risk in financial markets: How systemically important are insurers? In: *Journal of Risk and Insurance* 86(3), 729–59
- Kessler, D (2014). Why (re)insurance is not systemic. In: *Journal of Risk and Insurance* 81(3), 477–87
- Klein, RW (2012). Principles for insurance regulation: An evaluation of current practices and potential reforms. In: *The Geneva Papers* 37, 175–99
- (2013). Insurance market regulation: Catastrophe risk, competition and systemic risk. In: *Handbook of Insurance*. Ed. by G Dionne., 2nd ed. New York: Springer, 909–39
- Knot, K (2014). Governance of macroeconomic policy. Macroprudential policies: Implementation and interactions, *Financial Stability Review*. Banque de France
- Koijen, RSJ & Yogo, M (2017). *Risk of life insurers: Recent trends and transmission mechanisms*. Working Paper No. 23365. National Bureau of Economic Research

- KPMG (2022). The South African insurance industry survey 2022. KPMG South Africa
- Lee, SH (2013). Systemic liquidity shortages and interbank network structures. In: *Journal of Financial Stability* 9(1), 1–12
- Leukes, C & Odei-Mensah, J (2019). Systemic risk contribution of financial institutions in South Africa. In: *African Review of Economics and Finance* 11(2), 188–218
- Llewellyn, DT (1999). The economic rationale for financial regulation. Occasional Paper Series No. 1. Financial Services Authority
- Martinez-Jaramillo, S, Alexandrova-Kabadjova, B, Bravo-Benitez B & Solórzano-Margain JP (2015). An empirical study of the Mexican banking system's network and its implications for systemic risk. In: *Journal of Economic Dynamics & Control*, 20, 70–81
- MAS (2015). Objectives and principles of financial supervision in Singapore. April, 2004, revised in September 2015. Monetary Authority of Singapore
- Merton, RC (1995). A functional perspective of financial intermediation. In: *Financial Management* 24(2), 23–41
- Michael, B, Goo, S & Osaulenko, S (2010). Does objectives-based financial regulation imply a rethink of legislatively mandated economic regulation? A literature review. In: *Journal of Legislation* 46(2), 245–75
- Neale, FR, Drake, PP, Schorno, P & Semaan, E (2012). *Insurance and interconnectedness in the financial services industry*. Working Paper. UNC Charlotte
- Nier, E, Yang, J, Yorulmazer, T & Alentorn, A (2007). Network models and financial stability. In: *Journal of Economic Dynamics and Control* 31, 2033–60
- NTSA (2011). *A safer financial sector to serve South Africa better*. Policy Document. National Treasury, Government of South Africa
- OECD (2010). *Policy framework for effective and efficient financial regulation: General guidance and high-level checklist*. Organisation for Economic Cooperation and Development Publishing, Paris
- Park, SC & Xie, X (2014). Reinsurance and systemic risk: The impact of reinsurer downgrading on property-casualty insurers. In: *Journal of Risk and Insurance* 81(3), 587–622
- Pinter, G (2023). *An anatomy of the 2022 gilt market crisis*. Staff Working Paper No. 1,019. Bank of England
- Poledna, S, Molina-Borboa, JL, Martínez-Jaramillo, S, van der Leij, M & Thurner, S (2015). The multi-layer network nature of systemic risk and its implications for the costs of financial crises. In: *Journal of Financial Stability* 20, 70–81
- Prudential Authority (2019). Annual Report 2018/19. Prudential Authority, South African Reserve Bank
- (2021). *Regulatory strategy 2021–2024*. Prudential Authority, South African Reserve Bank
- (2022a). *2021 Life insurance industry experience*. Prudential Authority, South African Reserve Bank
- (2022b). Annual Report 2021/22. Prudential Authority, South African Reserve Bank
- (2022c). *Non-life industry experience 2022*. Prudential Authority, South African Reserve Bank.
- Radice, MP (2010). *Assessing the potential for systemic risks in the insurance sector: Considerations on insurance in Switzerland*. Working Paper June/2010. FINMA: Swiss Financial Market Supervisory Authority

- Rae, RA, Barrett, R, Brooks, D, Chotai, MA, Pelkiewicz, AJ & Wang, C (2017). *A review of Solvency II: Has it met its objectives?* Solvency II Working Party. Institute and Faculty of Actuaries
- Rusconi, RD (2020). The contribution of South Africa's insurers to systemic risk: Thoughts for policymakers. In: *South African Actuarial Journal*, 20, 149–210
- Russell, DT, Fier, SG, Carson, JM and Dumm, RE (2013). An empirical analysis of life insurance policy surrender activity. In: *Journal of Insurance Issues* 36(1), 35–57
- Safa, MF, Hassan, MK & Maroney, NC (2013). AIG's announcements, Fed's innovation, contagion and systemic risk in the financial industries. In: *Applied Financial Economics* 23(6), 1337–48
- SARB (2017a). *Financial Stability Review 2017: First Edition*. South African Reserve Bank
- (2017b). *Financial Stability Review 2017: Second Edition*. South African Reserve Bank
- (2018a). *Financial Stability Review 2018: First Edition*. South African Reserve Bank
- (2018b). *Financial Stability Review 2018: Second Edition*. South African Reserve Bank
- (2019). *Financial Stability Review 2019: Second Edition*. South African Reserve Bank
- (2020a). *Financial Stability Review 2020: First Edition*. South African Reserve Bank
- (2020b). *Financial Stability Review 2020: Second Edition*. South African Reserve Bank
- (2021a). *Financial Stability Review 2021: First Edition*. South African Reserve Bank
- (2021b). *Financial Stability Review 2021: Second Edition*. South African Reserve Bank
- (2022). *Financial Stability Review 2022: First Edition*. South African Reserve Bank.
- Schmukler, S (2004). *Benefits and risks of financial globalization: Challenges for developing countries*. Development Research Group. The World Bank
- Schwarcz, D & Schwarcz, SL (2014). Regulating systemic risk in insurance. In: *University of Chicago Law Review* 81, 1569–640
- Schwarcz, SL (2008). Systemic risk. In: *Georgetown Law Journal*, 97, 193–248
- (2014). Systematic regulation of systemic risk. In: *Wisconsin Law Review* 2019, 1–53
- Sedunov, J (2016). What is the systemic risk exposure of financial institutions? In: *Journal of Financial Stability* 24, 71–87
- Segoviano, MA & Goodhart, C (2009). *Banking Stability Measures*. Working Paper 09/04. International Monetary Fund
- Silva, W, Herbert, R & Vinicius, AS (2017). An analysis of the literature on systemic financial risk: A survey. In: *Journal of Financial Stability* 28, 91–114
- Sinha, A (2012). *Financial Sector Regulation and Implications for Growth*. BIS Papers No. 62. Bank for International Settlements
- Swarup, A (2012). A well-intentioned folly: The macroeconomic implications of Solvency II. In: *Economic Affairs* 32(3), 17–23
- Tagoe, NA (2016). The emerging role of financial intermediaries in the financial market of Ghana. In: *Business and Economics Journal* 7(4), 1000253
- Trichet, JC (2005). Financial stability and the insurance sector. In: *Geneva Papers on Risk and Insurance – Issues and Practice* 30, 65–71
- Van Lelyveld, I, Liedorp, F & Kampman, M (2019). An empirical assessment of reinsurance risk. In: *Journal of Financial Stability* 7, 191–203
- Wagner, W (2010). A note on the appropriate choice of risk measures in the solvency assessment of insurance companies. In: *Journal of Risk Finance* 15(2), 110–30

- Weiß, GNF & Mühlnickel, J (2014). Why do some insurers become systemically relevant? In: *Journal of Financial Stability* 13, 95–117
- Wong, A & Fong, T (2010). *Analysing Interconnectivity Among Economies*. Working Paper 03/2010. Hong Kong Monetary Authority
- World Bank (2012). *Rethinking the Role of the State in Finance*. Global Financial Development Report 2013. The World Bank
- Zhang, Q, Vallasca, F, Keasey, K & Cai, CX (2015). Are market-based measures of global systemic importance of financial institutions useful to regulators and supervisors? In: *Journal of Money, Credit and Banking* 47(7), 1403–42

APPENDIX A

List of financial reports consulted

Discovery (2018a). *Annual Financial Statements for the year ended 30 June 2018*, Discovery Limited

Discovery (2018b). *Integrated Annual Report for the year ended 30 June 2018*, Discovery Limited

Discovery (2019a). *Annual Financial Statements for the year ended 30 June 2019*, Discovery Limited

Discovery (2019b). *Integrated Annual Report for the year ended 30 June 2019*, Discovery Limited

Discovery (2020a). *Annual Financial Statements for the year ended 30 June 2020*, Discovery Limited

Discovery (2020b). *Integrated Annual Report for the year ended 30 June 2020*, Discovery Limited

Discovery (2021a). *Annual Financial Statements for the year ended 30 June 2021*, Discovery Limited

Discovery (2021b). *Integrated Annual Report for the year ended 30 June 2021*, Discovery Limited

Discovery (2022a). *Annual Financial Statements for the year ended 30 June 2022*, Discovery Limited

Discovery (2022b). *Integrated Annual Report for the year ended 30 June 2022*, Discovery Limited

Hollard (2017a). *Audited consolidated annual financial statements for the year ended 30 June 2017*,
The Hollard Insurance Company Limited

Hollard (2018a). *Audited consolidated annual financial statements for the year ended 30 June 2018*,
The Hollard Insurance Company Limited

Hollard (2019a). *Audited consolidated annual financial statements for the year ended 30 June 2019*,
The Hollard Insurance Company Limited

Hollard (2020a). *Audited consolidated annual financial statements for the year ended 30 June 2020*,
The Hollard Insurance Company Limited

Hollard (2021a). *Audited consolidated annual financial statements for the year ended 30 June 2021*,
The Hollard Insurance Company Limited

Hollard Life (2017b). *Audited consolidated annual financial statements for the year ended 30 June 2017*, Hollard Life Insurance Company Limited

Hollard Life (2018b). *Audited consolidated annual financial statements for the year ended 30 June 2018*, Hollard Life Insurance Company Limited

Hollard Life (2019b). *Audited consolidated annual financial statements for the year ended 30 June 2019*, Hollard Life Insurance Company Limited

Hollard Life (2020b). *Audited consolidated annual financial statements for the year ended 30 June 2020*, Hollard Life Insurance Company Limited

Hollard Life (2021b). *Audited consolidated annual financial statements for the year ended 30 June 2021*, Hollard Life Insurance Company Limited

Hollard Specialist (2019c). *Audited consolidated annual financial statements for the year ended 30 June 2019*, Hollard Specialist Insurance Company Limited

Hollard Specialist (2020c). *Audited consolidated annual financial statements for the year ended 30 June 2020*, Hollard Specialist Insurance Company Limited

Hollard Specialist (2021c). *Audited consolidated annual financial statements for the year ended 30 June 2021*, Hollard Specialist Insurance Company Limited

Liberty (2018a). *Annual Financial Statements for the year ended 31 December 2017*, Liberty Holdings Limited

- Liberty (2018b). *Group and Company annual financial statements for the year ended 31 December 2017*, Liberty Group Limited
- Liberty (2018c). *Integrated report for the year ended 31 December 2017*, Liberty Holdings Limited
- Liberty (2019a). *Annual Financial Statements for the year ended 31 December 2018*, Liberty Holdings Limited
- Liberty (2019b). *Group and Company annual financial statements for the year ended 31 December 2018*, Liberty Group Limited
- Liberty (2020a). *Annual Financial Statements for the year ended 31 December 2019*, Liberty Holdings Limited
- Liberty (2020b). *Group and Company annual financial statements for the year ended 31 December 2019*, Liberty Group Limited
- Liberty (2021a). *Annual Report for the year ended 31 December 2020*, Liberty Holdings Limited
- Liberty (2021b). *Annual Financial Statements for the year ended 31 December 2020*, Liberty Holdings Limited
- Liberty (2022a). *Annual Report for the year ended 31 December 2021*, Liberty Holdings
- Liberty (2022b). *Annual Financial Statements for the year ended 31 December 2021*, Liberty Group Limited
- Liberty (2022c). *Annual Financial Statements for the year ended 31 December 2021*, Liberty Holdings Limited
- MMI Holdings (2017). *Advancing MMI's Strategy: Financial Results 2017*, MMI Holdings Group
- MMI Holdings (2018). *Reset and Grow: Results for the year ended June 2018*, MMI Holdings Group
- Momentum (2019). *Summary of Financial Information: Audited results for the year ended June 2019*, Momentum Metropolitan
- Momentum (2020). *Group Annual Financial Statements: Audited results for the year ended June 2020*, Momentum Metropolitan
- Momentum (2021a). *Group Annual Financial Statements: Audited results for the year ended June 2021*, Momentum Metropolitan
- Momentum (2021b). *Integrated report 2021*, Momentum Metropolitan
- Momentum (2022a). *Group Annual Financial Statements: Audited results for the year ended June 2022*, Momentum Metropolitan
- Momentum (2022b). *Integrated report 2022*, Momentum Metropolitan
- Old Mutual (2020). *Integrated Report 2019*, Old Mutual Limited
- Old Mutual (2021). *Integrated Report 2020*, Old Mutual Limited
- Old Mutual (2019a). *Integrated Report 2018*, Old Mutual Limited
- Old Mutual (2019b). *Annual Financial Statements for the year ended 31 December 2018*, Old Mutual Limited
- Old Mutual (2022a). *Annual Financial Statements, consolidated and separate, for the year ended 31 December 2021*
- Old Mutual (2022b). *Integrated Report 2021*, Old Mutual Limited
- OMI (2018). *Annual Report 2017*, Old Mutual Insure Limited
- OMI (2019). *Annual Report 2018*, Old Mutual Insure Limited
- OMI (2020). *Annual Report 2019*, Old Mutual Insure Limited

OMI (2021). *Annual Report 2020*, Old Mutual Insure Limited

OMI (2022). *Annual Report 2021*, Old Mutual Insure Limited

OMLACSA (2018). *Separate and Consolidated Annual Financial Statements for the year ended 31 December 2017*, Old Mutual Life Assurance Company (South Africa) Ltd

OMLACSA (2019). *Annual Financial Statements for the year ended 31 December 2018*, Old Mutual Life Assurance Company (South Africa) Ltd

OUTsurance (2017). *Annual report 2017*, OUTsurance Holdings Limited

OUTsurance (2018). *Annual report 2018*, OUTsurance Holdings Limited

OUTsurance (2019). *Annual report 2019*, OUTsurance Holdings Limited

OUTsurance (2020). *Annual report 2020*, OUTsurance Holdings Limited

OUTsurance (2021). *Annual report 2021*, OUTsurance Holdings Limited

Sanlam (2018a). *Integrated Report 2017*, Sanlam

Sanlam (2018b). *Audited Annual Results 2017*, Sanlam

Sanlam (2019a). *Integrated Report 2018*, Sanlam

Sanlam (2019b). *Audited Annual Results 2018*, Sanlam

Sanlam (2020a). *Integrated Report 2019*, Sanlam

Sanlam (2020b). *Audited Annual Results 2019*, Sanlam

Sanlam (2021a). *Integrated Report 2020*, Sanlam

Sanlam (2021b). *Audited Annual Results 2020*, Sanlam

Sanlam (2022a). *Integrated Report 2021*, Sanlam

Sanlam (2022b). *Audited Annual Results 2021*, Sanlam

Sanlam Life (2018). *Annual Financial Statements 2017*, Sanlam Life Insurance Limited

Sanlam Life (2019). *Annual Financial Statements 2018*, Sanlam Life Insurance Limited

Sanlam Life (2020). *Annual Financial Statements 2019*, Sanlam Life Insurance Limited

Sanlam Life (2021). *Annual Financial Statements 2020*, Sanlam Life Insurance Limited

Sanlam Life (2022). *Annual Financial Statements 2021*, Sanlam Life Insurance Limited

Santam (2021). *Annual Financial Statements 2020*, Santam

Santam (2022). *Annual Financial Statements 2021*, Santam

APPENDIX B

Supporting information

TABLE 3. High-level classification of insurer contributions to systemic risk

Balance sheet element	Risk type	Detail and references
Assets	Concentration	Climate change and impact on asset prices (SARB, 2019) Exposure through investments (IAIS, 2011) Exposure to policy and governance (SARB, 2020a) Exposure to the economy (SARB, 2020a) Impact of investment returns on insurers (SARB, 2020b) Increasingly interconnected stock market performance (Acharya et al., 2010, 2011; Baluch et al., 2011; Bierth et al., 2019; Billio et al., 2012; Cummins & Weiss, 2013; Schwarcz & Schwarcz, 2014) Investment in banks and the real economy (SARB, 2017a, 2020a)
	Quality	Structured securities: liquidity and systemic impacts (Baluch et al., 2011; Baranoff, 2012; Chen et al., 2013; Cummins & Weiss, 2013, 2014; Geneva Association, 2010b; Klein, 2013; Trichet, 2005) Counterparty exposures (assets) (IAIS, 2018) Exploiting unregulated subsidiaries and information asymmetries (Acharya et al., 2011; Baranoff, 2012; Harrington, 2009; IAIS, 2011) Investing in complex structured securities (Cummins & Weiss, 2014) Non-traditional activities drive systemic risk (Cummins & Weiss, 2013; Neale et al., 2012)
Liabilities	Concentration	Catastrophe risk (Park & Xie, 2014) Impact of climate change on liabilities (SARB, 2020a) Correlated product classes (IAIS, 2011) Export credit insurance (poor substitutability) (IAIS, 2019) Exposure to business interruption claims (SARB, 2021b) Exposure to civil unrest (SARB, 2021b) Exposure to the economy (SARB, 2017b) Industry-loss warranties (IAIS, 2012b) Insurer concentration (SARB, 2020a, 2021b) Insurer interconnectedness (SARB, 2018b) Poor substitutability (Cummins & Weiss, 2014; IAIS, 2018) Poor substitutability and capacity concerns (IAIS, 2011) Poor substitutability: marine and aviation classes (IAIS, 2019) Poor substitutability: mortgage insurance class (IAIS, 2019) Reinsurance with limited or no risk transfer (IAIS, 2011)
	Mismatch	Annuities with options and guarantees (Cummins & Weiss, 2013) Embedded options (early surrender, liquidity risk) (IAIS, 2019) Financial guarantees: liquidity impacts (Cummins & Weiss, 2013, 2014; Geneva Association, 2010b; IAIS, 2011) Fixed-benefit guarantees (macro-economic exposure) (IAIS, 2019)

Balance sheet element	Risk type	Detail and references
Liabilities (continued)	Mismatch (continued)	Guarantee funds (Cummins & Weiss, 2014) Guaranteed returns on saving products (IAIS, 2018) Guarantees without matching (IAIS, 2018) Policyholder lapses and surrenders (SARB, 2018a, 2020a,b) Products with guarantees (Geneva Association, 2011) Providing financial guarantees (Cummins & Weiss, 2014) Saving and investment in long-term insurance (IAIS, 2011)
	Quality	Complexity (Cummins & Weiss, 2014) Complexity (low for non-life insurers) (Park & Xie, 2014) Product design more like banks (IAIS, 2011)
	Strategic	Bancassurance (IAIS, 2011) Credit protection and associated macro-economic exposure (IAIS, 2019) Exposure to burden of disease and economic impacts (SARB, 2021a) Exposure to business interruption claims (SARB, 2020b) Exposure to fraudulent activity (SARB, 2021b) Functions critical to the financial sector (IAIS, 2018) Insurance provides critical function with few substitutes (IAIS, 2019) Third-party asset management (IAIS, 2011)
	Operational	Cyber risk (IAIS, 2018)
ALM	Mismatch	Asset lending (Acharya et al., 2011; Besar et al., 2011; Cummins & Weiss, 2014; IAIS, 2018) Asset lending: liquidity risk (IAIS, 2018) Asset liquidation (IAIS, 2018) Constraining funding or liquidity (exposure channel) (IAIS, 2019) Contributing to asset volatility (asset liquidation) (IAIS, 2019) Derivatives (liquidity risk) (IAIS, 2018, 2019) Exacerbating market movements (asset liquidation) (IAIS, 2019) Excessive reliance on short-term financing (Cummins & Weiss, 2014) High equity levels in life insurance (Chen et al., 2013; Harrington, 2009; IMF, 2009) Liquidity risks (Cummins & Weiss, 2014) Liquidity: backing liquid liabilities with illiquid assets (IAIS, 2018) Maturity mismatches (Cummins & Weiss, 2014) Securities lending (liquidity risk) (IAIS, 2019) Short-term funding potentially leading to fire sales (Acharya et al., 2011; Besar et al., 2011; Geneva Association, 2010a,b; Jobst, 2014; Schwarcz & Schwarcz, 2014) Speculative derivatives (macro-economic exposure) (IAIS, 2019) Counterparty exposures (reinsurers) (IAIS, 2019)
	Quality	Alternative risk transfer (Cummins & Weiss, 2009; IAIS, 2011) Asset concentration (counterparty exposure) (IAIS, 2019) Banking and hedge fund activities (IAIS, 2011) Derivatives (liquidity risk) (IAIS, 2011) Lending interaction (counterparty exposure) (IAIS, 2019)

Balance sheet element	Risk type	Detail and references
ALM (continued)	Quality (continued)	Property management (IAIS, 2011) Synthetic investment portfolios (IAIS, 2011) Business model: mix of risks (IAIS, 2011)
	Strategic	Growth in non-core activities (Baluch et al., 2011) Insurance-linked securities (IAIS, 2011) Interconnectedness of various types (Cummins & Weiss, 2014) Size of exposures (Cummins & Weiss, 2014) Hierarchical link to reinsurers insufficient (IAIS, 2012a; Park & Xie, 2014)
Solvency	Concentration	Transferring losses to other participants (exposure channel) (IAIS, 2019) Leverage (IMF, 2009)
	Mismatch	Funding structure (IMF, 2009)
	Quality	Rapid growth (IAIS, 2011)
	Strategic	Deficient provisioning and inadequate pricing (IAIS, 2011)
	Operational	Limited fungibility within insurance groups (Baranoff, 2012; Radice, 2010) Under-reserving or under-pricing (IAIS, 2018) Government policy and regulation (Cummins & Weiss, 2014)
General	General	Interconnectedness higher than previously thought (Acharya et al., 2010; Billio et al., 2012) Life insurance more concentrated (IAIS, 2011) Panic run possible (Acharya & Richardson, 2014) Regulation: not primarily to reduce systemic risk (IAIS, 2011) Regulation: disadvantages of convergence (IAIS, 2011) Inadequate governance (IMF, 2022b)

TABLE 4. Selection of approaches to modelling systemic risk

Ellis type*	Summary of approach	Contagion direction	Data sources
Capital	Propensity to be under-capitalised when the system is under-capitalised (Acharya et al., 2010)	Market to entity	Book & market
	Capital shortfall of a company conditional on a market crisis (Acharya et al., 2012)	Market to entity	Book & market
	State-dependent sensitivity VaR to show dependence on state of financial markets (Adams et al., 2014)	Entity to market	Market
	Impact of entity distress on the value at risk of the financial system (Adrian & Brunnermeier, 2016)	Entity to market	Book & market
	Capital shortfall of a company conditional on a market crisis (Brownlees & Engle, 2017)	Market to entity	Book & market
	Joint probability of default: system tail risk, based on CDS data (Segoviano & Goodhart, 2009)	No direction implied	Market
	Various approaches to study insurance contribution to systemic risk (Weiß & Mühlnickel, 2014)	Several approaches	Book & market
	Based on sovereign CDS in Asia-Pacific, shows interconnectedness between countries (Wong & Fong, 2010)	Entity to market	Market
Contagion	Econometric connectedness on principal component analysis and Granger causality networks (Billio et al., 2012)	Between entities	Market
	Granger causality between banks and insurers using market and CDS prices (Chen et al., 2013)	Between entities	Market
Early warning	Granger causality between market returns of entities (Billio et al., 2012)	Between entities	Market
	Systemic risk metrics derived from CDS prices (Giglio, 2016)	No direction implied	Market
	Price of insurance against financial distress using CDS and equity price co-movements (Huang et al., 2012)	Entity to market	Market
Liquidity	Impact of shocks on individual banks and the system using Bayesian VaR (Aikman et al., 2011)	Market to entity	Book & market
	Several approaches to marginal impact of liquidity shortfall on market statistics (Jobst, 2014)	Entity to market	Book & market
Liquidity / Network	Liquidity shortages due to bank inter-connectedness: six network structures (Lee, 2013)	Between entities	Simulated
Network	Time-varying marginal effect of firm's VaR on system VaR, allowing for system interdependence (Hautsch et al., 2015)	Entity to market	Book & market
	Study of dynamics of interbank exposures and payment system networks (Martinez-Jaramillo et al., 2015)	Between entities	Book & market
	Quantify contribution to systemic risk from four distinct types of financial exposure (Poledna et al., 2015)	Between entities	Book & market

* The Ellis type follows the classification system proposed by Ellis et al.(2022). The acronym VaR in the summary of approach denotes Value at Risk. Contagion direction describes the nature of the relationship between individual entities and the market as a whole that the modelling aims to demonstrate. Market information is from quoted stock-price or CDS data and book values are obtained from accounting information.

Technical experts as managers and servant leaders

By Twané Wessels and Jeremias Jesaja de Klerk

Submission date 10 October 2023

Acceptance date 5 November 2023

ABSTRACT

The main aim of this research was to explore how a servant leadership style can assist technical experts as managers to become more effective leaders. Secondary objectives included exploring the leadership challenges that technical expert managers experience, the factors that make it harder or easier for a technical expert to be a servant leader and investigating to what extent servant leadership can be relevant to their context. Qualitative research through semi-structured interviews was conducted. We found that technical expert managers mostly experience interpersonal and time capacity challenges. Emerging technical experts prefer a technical expert as a manager for guidance and mentorship, making it easier for technical expert managers to assume a servant leadership style. Having an intrinsic legacy motive beyond just making a technical contribution promotes a servant leadership style. Organisational culture and an organisation's stage in its growth cycle can make it harder or easier to adopt a servant leadership style. Our findings further confirm that servant leadership includes a purpose of empowerment, encouraging technical expert managers to delegate more. Time constraints and several interpersonal leadership challenges may be mitigated because servant leaders tend to operate from a stronger relationship domain which helps to enhance a technical expert manager's capacity to delegate. However, given work deliverables of technical expert managers, we conclude that an appropriate balance between transformational and servant leadership might be an even more advantageous leadership approach.

KEYWORDS

Leadership challenges; effective leadership; servant leadership; technical expert; transformational leadership

CONTACT DETAILS

Mrs Twané Wessels, Bond Business School, Bond University, Gold Coast, Australia

email: twessels@bond.edu.au

Professor Mias de Klerk, Stellenbosch Business School, Stellenbosch University, Bellville, South Africa; email: mias@usb.ac.za

1. INTRODUCTION

1.1 Many organisations promote technical experts with little or no prior leadership experience to managerial positions without providing them with relevant leadership development experience (Panagiotopoulos, 2010). This lack of leadership development and experience may cause leadership challenges for technical experts as managers. Effective leadership is important because there is a positive relationship between effective leadership and organisational performance (Abbas & Daniel, 2019).

1.2 An expert is someone widely recognised as a reliable source of knowledge, technique, or skill whose judgement is accorded authority and status by the public or their peers (Panagiotopoulos, 2010). Leadership by a technical expert may be preferable in situations demanding elevated levels of technical knowledge and expertise. However, although experts may be strong in the technical domain, they often struggle in the relationship domain. The basis of the relationship domain includes capabilities like collaboration, stakeholder management and knowledge sharing (Gordon, 2020). Technical experts have often not developed these capabilities well because their training tends to focus on cognitive abilities and technical skills rather than interpersonal or leadership skills (Taylor & Benbow, 2016). Therefore, although technical experts' strong technical knowledge may support them as leaders, their underdevelopment in the relationship domain may present a leadership challenge.

1.3 'The tyranny of competence' presents another leadership challenge and refers to when an individual leads from their technical expertise rather than from what is required at the time (Quinn, 1996: 115–20). In the absence of collaboration, the rising demands for this individual can often turn their focus to getting the job done, and when helping subordinates, they may then offer a quick answer or a complete solution. If technical experts as managers continuously offer this type of dependency-orientated help and do not share their knowledge, their subordinates may remain dependent on them because they do not learn the skills needed to solve problems themselves in future (Alvarez & Van Leeuwen, 2011). The converse of not sharing knowledge easily is that a technical expert may also not easily accept advice from others. A technical expert has expert power, often leading to competitiveness and overconfidence that may inhibit advice-taking (Tost et al., 2012). Not taking advice and not considering alternative views are referred to as the paradox of power, and this lack of balanced information processing creates another leadership challenge for the technical expert that can hamper improved decision-making (Rego et al., 2018).

1.4 Developing a coaching style of leadership like servant- or transformational leadership may assist with the leadership challenges that a technical expert may experience as a manager. Studies have shown that servant- and transformational leadership result in many positive outcomes (Smith et al., 2004; Stone et al., 2004). Greenleaf (1998) conceptualised servant leadership, which involves leaders being humble and authentic and serving the needs of their subordinates as their top priority. Servant leaders provide stretching assignments and empower their subordinates with self-responsibility (Van Dierendonck, 2011). On the other hand, transformational leaders build commitment to organisational objectives by inspiring subordinates towards a shared vision and empowering them to achieve it (Smith et al., 2004). A big difference between transformational leadership and servant leadership is that transformational leaders focus primarily on organisational objectives while servant leaders focus primarily on the growth of their subordinates (Stone et al., 2004).

1.5 The focus on subordinates by servant leadership potentially offers multiple benefits to technical experts as managers to address the specific leadership challenges considered. First, leader humility positively impacts subordinate performance (Mao et al., 2019). Secondly, organisational trust, citizenship behaviour, collaboration and tacit knowledge sharing are likely to increase when servant leadership is adopted (Chatbury et al., 2011; Karatepe et al., 2019; Parris & Peachy, 2013; Whisnant & Khasawneh, 2014). In turn, organisational trust supports employees' morale and is likely to promote organisational commitment and performance (Katou, 2015). An empowerment culture can help organisations maintain a sustainable competitive advantage (Ghosh, 2013). Finally, by developing leadership skills through self-actualisation and transcending to a cause greater than themselves by focusing on their subordinates, technical experts may find more meaning in their careers (Frankl, 2008: 114–5).

1.6 As far as could be established, research has not explicitly addressed the application of servant leadership by technical experts as managers to address the leadership challenges they may experience. These leadership challenges may be effectively resolved or mitigated by the technical expert adopting a servant leadership style. Servant leadership may be efficient in supporting the technical expert as manager to be a more effective leader. This research investigates how servant leadership can be relevant to technical experts as managers and how adopting a servant leadership approach can support technical experts to become more effective leaders by resolving the leadership challenges they may experience. It further investigates which factors make it easier or harder for technical experts to be servant leaders to establish how technical experts can be assisted to become servant leaders. Servant leadership may efficiently support technical experts to be more effective leaders to the benefit of the organisation, subordinates, and the technical expert him or herself.

2. LITERATURE REVIEW

2.1 Leadership challenges of technical experts

2.1.1 An expert is defined as someone widely recognised as a reliable source of knowledge, technique, or skill whose judgement is accorded authority and status by the

public or their peers (Ackerman et al., 2003; Panagiotopoulos, 2010). In some cases, expert leadership may be preferable because they have a deep understanding of their particular field of expertise and set a high technical quality standard (Goodall, 2010). For example, the lack of expert knowledge at the top of organisations may have contributed to the economic turmoil in 2008 because some CEOs lacked the knowledge necessary to fully understand the core business of their organisations (Goodall, 2010). Therefore, a technical expert can be an asset to the business as a leader.

2.1.2 Many organisations promote technical experts to managerial positions based on past technical performance or often due to organisational necessities, without providing them with relevant leadership development experience (Panagiotopoulos, 2010). This lack of leadership development may lead to the Peter Principle, which refers to a promoted person lacking the skills required for the new role, leading to incompetency at the new level, which may hinder further promotion (Peter & Hull, 1969: 166–7). Hence, technical experts may experience leadership challenges as managers. However, the promotion of technical expertise should not mean the demotion of management proficiency. Promoting technical experts as managers must be preceded by leadership development experience or project management training (Panagiotopoulos, 2010). A technical expert manages technical matters as a primary responsibility and managerial issues as a secondary responsibility, which may result in leadership challenges. In being promoted to manager, the priority must be reversed (Panagiotopoulos, 2010).

2.2 Technical experts in the interpersonal domain

2.2.1 Although experts tend to be strong in the technical domain, they often struggle in the relational domain (Gordon, 2020). Technical experts have often not developed interpersonal or leadership skills well, with their training focusing on cognitive abilities and technical skills (Taylor & Benbow, 2016). In contradiction, the relationship domain requires capabilities such as collaboration, the ability to influence without authority, coaching others, stakeholder management and knowledge sharing (Gordon, 2020). These interpersonal skills can also be referred to as ‘the practical intelligence of professionals’ or ‘soft skills’ (Joseph et al., 2010). The term ‘soft skills’ may be misleading and diminish the importance and complexity of these skills because they are often much harder to learn than many technical skills, also known as so-called ‘hard skills’ (Johnston & McGregor, 2005). Nevertheless, there is much evidence that technical competence and interpersonal skills are needed for effective leadership and professional practice (Joseph et al., 2010). Developing interpersonal skills to support technical skills can improve personal productivity, collaboration, and synergy (Bancino & Zevalkink, 2007). Consequently, developing interpersonal skills can strengthen technical experts’ capabilities in the relationship domain.

2.2.2 Technical disciplines have been notoriously poor at developing future leaders for corporate leadership positions despite technical professions increasingly requiring a broader skillset (Bancino & Zevalkink, 2007). Technical professions require a broader skillset in today’s fast-paced marketplace to improve the bottom line and due to increasing competition in a globalised economy. Therefore, it will benefit technical professions if interpersonal training

elements are integrated directly into technical training programmes. Interpersonal skills training differs from technical skills learning and comes from exposure to real-world examples and situations, cooperative work, and teamwork (Taylor & Benbow, 2016).

2.3 The tyranny of competence

2.3.1 Many people build their identity around their knowledge and competence in employing certain known techniques or abilities (Quinn, 1996: 3). ‘The tyranny of competence’ occurs when an individual manages from their technical experience rather than with interdependent action that may be required at the time (Quinn, 1996: 115–20). The rising demands for this individual in the absence of collaboration can turn their focus to getting the job done, and when helping subordinates, they may offer a quick answer or a complete solution (Alvarez & Van Leeuwen, 2011; Quinn, 1996: 115–20). If technical experts as managers continually offer this type of dependency-orientated help and do not share their knowledge, their subordinates may remain dependent on them because they do not learn the skills to solve problems themselves in future (Alvarez & Van Leeuwen, 2011). Helping subordinates by offering a quick answer or complete solution or being a ‘rescuer’ is a leader’s most common accidental diminisher tendency (Wiseman, 2017: 195).

2.3.2 Subordinates may come to expect dependency-orientated help from technical experts, but it may negatively impact the respect for experts as leaders in the long run, which poses a leadership challenge (Alvarez & Van Leeuwen, 2011; Magee & Galinsky, 2008). Furthermore, in the long run, if subordinates are not empowered to solve problems themselves, they may experience frustration and depleted confidence (Wiseman, 2017: 195). In contrast, investing in subordinates’ success, sharing knowledge, and empowering subordinates may lead to subordinates gaining more self-competence and self-confidence, feeling more respected and, finally, employee satisfaction (Alvarez & Van Leeuwen, 2011; Wiseman, 2017: 195).

2.4 Knowledge sharing

2.4.1 In today’s economy, it is increasingly the case that most work is knowledge work and therefore, it is important to overcome the barriers to transferring expertise within organisations (Hinds & Pfeffler, 2003: 24). Human nature can pose a barrier to information or knowledge sharing: for example, people may not share their ideas, fearing ridicule, or may withhold information to have power over others (Babcock, 2004). Experts face a conflict of interest or a social dilemma in knowledge sharing: from a group or society perspective, experts should share their knowledge; however, individually, they are better off not to do so because acquiring knowledge is costly, and they would give up their competitive advantage (Moser, 2017). There is a conflict of interest between the collective and the individual expert’s perspectives, and this conflict creates a challenge in knowledge management projects within organisations (Moser, 2017).

2.4.2 Considering the expert’s motivation for knowledge sharing may assist in achieving better knowledge sharing for their subordinates and the organisation’s benefit. Experts’ motivation for knowledge sharing relates to the indirect reciprocity theory (Moser,

2017). Experts may be more likely to cooperate in knowledge sharing if they receive indirect returns from status benefits and reputational gains for their contributions to the collective good (Moser, 2017; Rockenbach & Milinski, 2006). The indirect reciprocity theory then refers to when implicit ‘punishment’ costs are induced, for instance, when experts give up the opportunity to increase status and reputation by not cooperating in knowledge sharing (Rockenbach & Milinski, 2006).

2.4.3 Reducing an expert’s power status may lead to the expert disengaging from knowledge sharing (Issac et al., 2022). Systematic measures in the organisation, such as rotation policies and a reduction in hierarchical relationships, may lessen uncontrolled changes in power statuses within an organisation and therefore support knowledge sharing (Issac et al., 2022). A reduction in hierarchical relationships will reduce the power distance between experts and their subordinates and support better knowledge sharing. A culture of knowledge sharing and collective thinking in an organisation supports an organisation’s competitive advantage and performance (Collinson & Wilson, 2006; Gutierrez et al., 2015).

2.5 The paradox of power

2.5.1 A technical expert has expert power that may often lead to competitiveness and overconfidence, inhibiting advice-taking (Tost et al., 2012). Incorporating and seeking employee voice is essential to organisational performance. Yet, some managers display an aversion to suggestions from subordinates to compensate for a threatened ego and a perception that they will be seen as having less ability or competence associated with their managerial roles (Fast et al., 2014). The paradox of power refers to situations where greater decision rights are often coupled with power-induced neglect of the judgement of others or when advice from others is undervalued, and opinions are overvalued (Bonaccio & Dalal, 2006; Tost et al., 2012). Yet, acquiring information from broader perspectives and differing opinions is arguably the easiest way to improve decision-making (Larrick, 2009). Humble leaders have a more comprehensive and richer array of information and knowledge at their disposal to make better-informed decisions and improve effective team performance (Fast et al., 2014; Tangney, 2009).

2.5.2 Balanced information processing refers to the degree to which a leader objectively considers data and alternative views before making informed and improved decisions (Rego et al., 2018). The paradox of power and a lack of balanced information processing may mean that some technical experts underutilise the intelligence around them and make solo decisions. On the other hand, leaders who encourage an exchange of views create the safety for best thinking and then engage people to achieve sound decisions and develop collective intelligence (Wiseman, 2017: 129–156).

2.6 Effective leadership

Effective leadership is growing in importance because no one person can deal with the rapid pace of change and complexity of the environment in which many organisations operate (Nahavandi, 2015). The leadership challenges that technical experts may experience as managers can hinder their effective leadership. Leadership effectiveness is related to inter-

personal behaviours that can positively influence change, group performance and follower satisfaction (Yukl, 2012). Effective leaders can motivate, inspire, empower and influence subordinates and positively influence organisational performance (Abbas & Daniel, 2019; Cote, 2017). Leaders are effective when their subordinates achieve their specified goals; they achieve smooth internal processes like group cohesion and follower satisfaction and enable external adaptability (Nahavandi, 2015: 5). A successful manager may not necessarily be an effective leader. Sometimes, successful managers get promoted quickly but do not necessarily have satisfied and productive employees (Luthans, 1988). Effective leadership must not only be measured by an individual's personal career success but also by the influence a leader has on subordinates.

2.7 Servant leadership

2.7.1 Transactional leadership, which is based on bureaucratic authority, focuses on task completion, and relies on rewards and punishments (Klijn et al., 2022). Transformational and servant leadership differ significantly from transactional leadership as they both involve a coaching style of leadership, which may assist a technical expert with the leadership challenges experienced as a manager. Organisations with leaders who embrace a coaching style of leadership will continue to be successful in the emerging global economy because these organisations generate a steady pipeline of capable leaders (Kumar & Provodnikova, 2005). At first glance, transformational and servant leadership appear to be somewhat similar. Transformational leaders and servant leaders are visionaries, generate high levels of trust, serve as role models, show consideration for others, delegate responsibilities, empower subordinates, teach, communicate, listen, and influence subordinates (Stone et al., 2004). However, an in-depth study of the literature indicates that transformational and servant leadership can be distinguished from each other. Transformational leadership centres on organisational objectives and is a process of building commitment to the objectives in which a leader inspires subordinates towards a shared vision and then empowers them to achieve it (Smith et al., 2004). Greenleaf has conceptualised servant leadership as:

The [s]ervant-[l]eader is servant first ... It begins with the natural feeling that one wants to serve, to serve first. Then conscious choice brings one to aspire to lead ... The best test, and difficult to administer is this: Do those served grow as persons? Do they, while being served, become healthier, wiser, freer, more autonomous, and more likely themselves to become servants? (Greenleaf, 1998: 123)

2.7.2 The essence of servant leadership comes through clearly in Greenleaf's explanation. The focus of servant leaders is not on themselves but on their subordinates, and servant leaders' motivation is to serve their subordinates and see them grow. In servant leadership, the motivation for leadership moves to a higher plane of motivation to serve the needs of others (Luthans & Avalio, 2003). The servant leader is inclined to serve first, and the transformational leader is to lead first (Parolini, 2007: 64). A servant leader is 'primus inter pares' (first among equals) and does not use their power to get things done but rather uses persuasion (Frick, 2004: 121). The servant leader influences subordinates through non-

manipulative processes like service and encouraging stewardship rather than directing (Stone et al., 2004). Finally, servant leadership is a values-based approach to leadership that favours leadership as a relationship (Reinke, 2004).

2.7.3 Organisational concerns tend to be more peripheral for the servant leader (Patterson, 2003). Servant leaders trust subordinates to do what is necessary for the organisation, which, in turn, facilitates achieving organisational objectives as a secondary outcome (Stone et al., 2004). Servant leadership can support organisations in developing social responsibility strategies without sacrificing their financial goals (Kincaid, 2012). On the other hand, transformational leaders may focus more on achieving organisational goals in the short term, with less focus on the long-term benefits of the growth of subordinates or social responsibility strategies (Bharwaney, 2020: 6).

2.7.4 Scepticism about servant leadership may stem, in part, from a misunderstanding that equates service with weakness (Johnson, 2001: 137). Servant leadership does not imply an attitude of servility or that leaders would have low self-esteem but instead emphasises that it is the responsibility of the leader to increase the autonomy and responsibility of subordinates to encourage them to think for themselves (Bowie, 2000). Servant leaders empower subordinates with self-responsibility and provide stretching assignments, leading to career satisfaction and success (Wang et al., 2019). A leader must create a safe space within an intense environment that requires people's best thinking and work, with rapid learning cycles (Wiseman, 2017: 65–96). There is a difference between a tense environment that suppresses people's thinking and capability and an intense climate. The latter accesses significantly more brainpower from subordinates (Wiseman, 2017: 65–96). The outcome of servant leadership is that subordinates grow as persons; they become healthier, wiser, freer, and more autonomous (Greenleaf, 1998: 123).

2.7.5 A servant leader is characterised by the quality of goodness or moral excellence (Patterson, 2003). They build relationships on trust and interpersonal acceptance. Interpersonal acceptance is the ability to understand where people are coming from and to cognitively adopt the psychological perspectives of other people (Van Dierendonck, 2011). For servant leaders, it is important to create an atmosphere of trust where people feel accepted and are free to make mistakes, knowing they will not be rejected (Ferch, 2003: 10). Servant leaders provide direction to subordinates and empower and develop them (Van Dierendonck, 2011). The servant leader recognises, acknowledges, and believes in each individual's abilities and intrinsic value (Greenleaf, 1998: 7). Servant leaders look beyond their own intelligence and focus on extracting and extending the intelligence of others. In her book, *Multipliers*, Wiseman (2017: 1–32) coined the 'multiplier effect', which refers to leaders who apply their intelligence to amplify the intelligence and capability of people around them.

2.7.6 Servant leaders are humble and authentic, and their motives include stewardship (Van Dierendonck, 2011). The basis of stewardship philosophy includes trust and a long-term outlook and is about the collective serving of higher-order needs, beyond self-interest, within a low power distance context (Saltman & Ferroussier-Davis, 2000). Humility is the ability to keep one's accomplishments in perspective (Wadhwa & Mahant, 2022). There is a positive association between humble leadership and effective team performance

(Tangney, 2009). Authenticity can be described as behaving so that professional roles remain secondary to who the individual is as a person (Halpin & Croft, 1966).

2.7.7 Some scholars contend that a servant leadership model is more suited for a stable environment; therefore, the organisational growth cycle may influence servant leadership's effectiveness (Smith et al., 2004). The limited resource of time means that if experts spend time sharing their knowledge with subordinates, it may potentially lead to a decrease in the expert's level of performance, which may not be ideal for start-ups or growing organisations (Hinds & Pfeffer, 2003). In more mature organisations, concern for employees and their personal growth becomes more important to achieve effective leadership and employee satisfaction (Smith et al., 2004).

2.8 The benefits of servant leadership

2.8.1 BENEFITS TO THE ORGANISATION

2.8.1.1 Several studies indicated a strong correlation between trust and servant leadership (Dannhauser & Boshoff, 2006; Joseph & Winston, 2005; Reinke, 2003). Organisational trust leads to many positive outcomes, including organisational commitment, citizenship behaviour and collaboration (Chatbury et al., 2011; Dannhauser & Boshoff, 2006; Karatepe et al., 2019; Katou, 2015; Parris & Peachy, 2013). Organisational trust supports employee morale and, ultimately, organisational performance (Katou, 2015). Servant leadership promotes organisational performance through improved decision-making following a balanced process of information gathering and dynamic leadership (Stone et al., 2004; Van Dierendonck, 2011). Balanced information processing and dynamic leadership enable the leader to react to different situations and allow external adaptability and agility for the organisation (Nahavandi, 2015).

2.8.1.2 Through the multiplier effect (Wiseman, 2017: 1–32), servant leadership can help technical experts to extract the optimal potential and performance from a group while maintaining employee satisfaction. The multiplier effect is useful and relevant to address the problem of new demands and insufficient resources that organisations face today, particularly because of 'the great resignation' following the Covid-19 pandemic (Allen, 2015: 4; Sheather & Slattery, 2021). Servant leaders empower their subordinates. Creating an empowerment culture can help organisations maintain a sustainable competitive advantage (Ghosh, 2013). Leaders can provide the right degree of accountability when there are high-quality interpersonal relations between the leader and subordinates (Ferris et al., 2009). A leader must define opportunities that challenge people to go beyond what they know how to do, generate the belief that it is possible and connect the specific steps needed to create movement. Otherwise, a leader may limit the organisation to what only they know how to do (Wiseman, 2017: 97–128). Servant leadership can bring about deep change in organisations. Servant leaders strive to serve their subordinates, who serve the customer. As a result, employees are more likely to adopt a servant leadership approach themselves, which can lead to a decrease in customer churn and an increase in long-term profitability and success (Greenleaf, 1998: 123).

2.8.2 BENEFITS TO SUBORDINATES

2.8.2.1 The focus of servant leadership is on the servant leader's subordinates, leading to many benefits for the subordinates. Servant leadership leads to a commitment to subordinates' growth, development, and empowerment (Greenleaf, 1998: 7; Reinke, 2004). Servant leaders are authentic and show humility by acknowledging that they do not have all the answers (Reinke, 2004). Leader humility positively impacts subordinate performance (Mao et al., 2019). Servant leaders' interpersonal accepting attitude creates a safe psychological climate where subordinates feel respected, safe, and trusted to use their knowledge and to focus on continuous development and learning (Van Dierendonck, 2011). As a result, subordinates are likely to become wiser, freer, and more autonomous, which helps them discover the right solutions themselves (Greenleaf, 1998: 123; Van Dierendonck, 2011).

2.8.2.2 There is an indirect influence of servant leadership on subordinates through ethics and organisational justice. The leader's concern with ethics, particularly fostering stewardship, positively influences the organisation's culture to benefit employees (Reinke, 2004). In addition to employee empowerment, servant leadership is related to job satisfaction through organisational justice. Organisational justice leads to overall psychological need satisfaction and improves psychological well-being for subordinates (Mayer et al., 2008; Van Dierendonck, 2011).

2.8.3 BENEFITS TO THE TECHNICAL EXPERT AS MANAGER

2.8.3.1 As far as could be established, research has not explicitly addressed the application of servant leadership by technical experts as managers to address the leadership challenges they may experience. The leadership challenges that the technical expert may experience as a manager include challenges in the interpersonal domain, the tyranny of competence, lack of knowledge sharing and the paradox of power. These leadership challenges may be effectively resolved or mitigated by the technical expert adopting a servant leadership style. Servant leadership may be efficient in supporting the technical expert as manager to be a more effective leader. Table 1 demonstrates the potential leadership challenges of the technical expert as a manager in combination with the characteristics of servant leadership that may assist in resolving or mitigating the specific leadership challenge.

2.8.3.2 Overcoming leadership challenges and receiving positive assessments of leader performance and effectiveness can benefit the technical expert as manager by influencing their reputation as a leader through their effects on social and human capital (Hall et al., 2004). Technical experts as managers can mitigate the Peter Principle and open the door for further promotions by overcoming the leadership challenges they may experience and developing their leadership and interpersonal skills (Peter & Hull, 1969: 166–7). Transcending to a cause greater than themselves by focusing on their subordinates may lead to technical experts finding more meaning in their careers (Frankl, 2008: 114–5).

TABLE 1. How servant leadership can support technical experts to be effective leaders

Leadership challenge that the technical expert may experience	Servant leadership characteristics and the abilities of a servant leader that can potentially mitigate the leadership challenge
Technical experts in the relationship or interpersonal domain	Servant leaders move beyond self-interest and focus on their subordinates (Patterson, 2003; Stone et al., 2004). The servant leader's moral inclination is to serve first (Luthans & Avalio, 2003; Parolini, 2007). Servant leaders tend to operate from a stronger relationship domain because they generate high levels of trust, show concern for others, and communicate and listen well (Stone et al., 2004). A servant leader views leadership as a relationship (Reinke, 2004). Servant leaders' interpersonal accepting attitude creates a safe psychological climate where subordinates feel trusted (Reinke, 2004; Van Dierendonck, 2011). A stronger relationship domain tends to result in improved coaching, collaboration, and stakeholder management abilities to influence subordinates without using authority (Gordon, 2020).
The tyranny of competence	Servant leaders provide and delegate stretch assignments (Wang et al., 2019). Servant leaders provide direction, coach and teach subordinates but encourage autonomy and for subordinates to think for themselves (Alvarez & Van Leeuwen, 2011; Bowie, 2000; Parolini, 2007; Van Dierendonck, 2011; Wiseman, 2017: 195).
Knowledge sharing	The best leaders make everyone smarter through the 'multiplier effect' (Wiseman, 2017: 1–32). Experts may be more likely to cooperate in knowledge sharing if they receive indirect returns from status benefits and reputational gains for their contributions to the collective good (Rockenbach & Milinski, 2006). However, key dimensions of the servant leader's moral conscience are stewardship and sacrificial service (Van Dierendonck, 2011). Therefore, servant leaders may be more inclined to share knowledge for the collective good without the expectation of receiving direct or indirect returns and so assist in overcoming the barrier of knowledge sharing in organisations. Furthermore, servant leadership and stewardship operate within a low-power distance context, which also encourages more knowledge sharing (Saltman & Ferroussier-Davis, 2000).
The paradox of power	Humility and authenticity are core characteristics of servant leadership (Van Dierendonck, 2011). Through balanced information processing and being open to taking advice, humble leaders have a broader and richer array of information and knowledge at their disposal to make better-informed decisions and improve effective team performance (Fast et al., 2014; Tangney, 2009). Collaborating, utilising collective thinking and being open to employee voices further support improved decision-making (Fast et al., 2014; Wiseman, 2017: 129–56).

2.9 Factors that can make it easier or harder for technical experts as managers to be servant leaders

Some factors can make it easier or harder for technical experts to be servant leaders. Some of the factors evident in the literature are explored in the next sections.

2.9.1 FACTORS THAT CAN MAKE IT EASIER FOR TECHNICAL EXPERTS AS MANAGERS TO BE SERVANT LEADERS

2.9.1.1 CREDIBILITY, AUTHORITY, AND STATUS

A leader must understand the situation and environment they lead. A leader who is authoritative, professional and responsible is likely to be more successful than someone who does not have these characteristics (Nasor, 2019). Experts have a deep understanding of their area of expertise, and their status and credibility can enhance the respect for them and their power and influence as leaders (Goodall, 2010). Credibility is important for leaders to meaningfully engage with their subordinates because the leader's credibility offers a foundation of trust for the relationship between the leader and subordinates, which in turn supports an enabling and collaborative environment (Muli, 2022).

2.9.1.2 LEGACY MOTIVE

The expert may now be ready to transcend to a cause greater than their technical success, having achieved authority and status as an expert. The expert may desire to leave a legacy by supporting the development of future generations of experts. The legacy motive is a mechanism for channelling self-interest towards the pursuit of the long-term interests of the collective (Fox et al., 2015). Leaving a legacy means that an individual has established an impact that will persist into the future and will have a positive effect on others in future, leaving the world a little better off for their presence in it (Fox et al., 2015). Servant leadership strongly focuses on developing subordinates; therefore, servant leadership may support the expert to achieve their legacy motive.

2.9.1.3 ETHICAL CODES

Ethical codes of practice often apply to technical managers as professionals, protecting against conflicts of interest that might arise between a professional's and the organisation's demands. Servant leadership has an ethical grounding and can help to address the challenges and ethical dilemmas of the twenty-first century that include economic globalisation, increased communications, rising terrorism, war and violence, environmental degradation, the threat of global warming and the intensifying gap between the poor and rich worldwide (Parris & Peachy, 2013). As professionals and managers, technical experts may find it easier to associate with servant leadership. However, in the broader management field, enforcing a code of conduct with rigorous rules of professionalisation requires the management field to be ring-fenced and systematised, which is difficult and complex.

2.9.2 FACTORS THAT CAN MAKE IT HARDER FOR TECHNICAL EXPERTS AS MANAGERS TO BE SERVANT LEADERS

2.9.2.1 INTERPERSONAL LEADERSHIP SKILLS

2.9.2.1.1 Cognitive ease is lazy thinking and the mental stage that requires minimal effort for an individual with no significant active functioning of the brain's cognitive function (Kahneman, 2011: 59–70). A person gravitates towards simpler situations rather than complex ones because of cognitive ease. Applying interpersonal leadership skills may require more cognitive effort for technical experts due to the probable lack of development or experience in this area (Taylor & Benbow, 2016). Consequently, technical experts may prefer to operate from or gravitate towards their technical domain.

2.9.2.1.2 The technical expert may require deep change to operate more comfortably in the relational domain. The process of deep change requires new ways of thinking and behaving that distort existing thinking patterns (Quinn, 1996: 3). Deep change involves taking risks and surrendering control of the present self (Quinn, 1996: 45). It is difficult because individuals become structured and stagnant (Kahneman, 2011: 59–70). The journey of change is like 'travelling naked into the land of uncertainty' that requires one to forget what you know and discover what you need (Quinn, 1996: 3–14).

2.9.2.2 POWER DISTANCE

2.9.2.2.1 Individual-level power distance is defined as the extent to which subordinates expect and accept top-down direction from their leaders (Kirkman et al., 2009). High power distance makes subordinates more likely to follow and accept the hierarchy. In low power distance, individuals aim to distribute power equally. Expert power may create a higher power distance. A higher power distance may make it harder to be a servant leader. A culture with a low power distance is expected to be more encouraging toward developing servant leadership because the relationship between leader and follower is based on a more equal footing (Sousa et al., 2022). A reciprocal relationship with a strong focus on personal growth and less on self-protection is more likely to develop within a low power distance context. The servant leader relies on unconventional approaches to influence others, like the service itself, instead of using power and control (Parolini, 2007).

2.9.2.2.2 Experts, as high achievers, are likely to be motivated by opportunities to demonstrate their knowledge, master challenges and gain recognition (Moser, 2017). The desire to achieve is a major source of strength in business. However, an ethos of increasing personalised power and celebrating individual achievement can harm other motivations, such as the drive to empower people (Spreier et al., 2017). People high in socialised power get satisfaction from helping others feel stronger and more capable (Spreier et al., 2017). IBM successfully changed their culture from personal heroics and individual achievement to valuing socialised power, with managers paying attention to the greater needs of the company (Spreier et al., 2017). After IBM's metamorphosis, the use of a coaching style of leadership increased by 17%. Therefore, an environment that values socialised power will be more conducive to servant leadership.

2.9.2.3 PERCEIVED HUMILITY

Humility is a characteristic of servant leadership (Patterson, 2003; Van Dierendonck, 2011). The etymological origin of humility is based on the Latin word ‘humilis’ (on the ground), derived from the word ‘humus’ (earth). It follows that humility is a virtue that grounds and stabilises one’s self-perception (Park & Peterson, 2003). The more power the leader possesses, the more subordinates value their humility, and it can increase their motivation to follow (Sousa & Van Dierendonck, 2017). However, experts with high expert power may not always be perceived as humble because of the lack of considering alternative views or inhibited advice-taking (Rego et al., 2018). Lower perceived humility can make servant leadership harder and decrease subordinates’ motivation to follow.

2.9.2.4 ‘YOU DO NOT KNOW WHAT YOU DO NOT KNOW’ PROBLEM

Experts do not generally ask for leadership development assistance because they tend to be intelligent, successful and may be proud, or they don’t want to be managers (Gordon, 2020). However, technical experts as managers could benefit from the help and support of human resource development professionals. Human resource development professionals are called to address the ‘you do not know what you do not know’ problem by offering experiential learning opportunities that develop interpersonal skills and are internalised through a self-reflective process (Gordon, 2020; Cseh et al., 2013; Taylor & Benbow, 2016).

3. PROBLEM STATEMENT AND OBJECTIVES OF THE RESEARCH

3.1 Problem statement

3.1.1 Experts’ leadership in managerial positions may be preferable in some cases because they have a deep understanding of their field of expertise and set a high technical quality standard (Goodall, 2010). However, many organisations promote technical experts with little or no leadership experience to managerial positions without providing them with relevant leadership development experience (Panagiotopoulos, 2010). This shortage of leadership development and experience may cause interpersonal leadership challenges for technical experts as managers and hinder effective leadership. Leadership challenges may include an underdeveloped interpersonal domain (Gordon, 2020; Joseph et al., 2010; Taylor & Benbow, 2016); the tyranny of competence (Alvarez & Van Leeuwen, 2011; Magee & Galinsky, 2008; Quinn, 1996: 115–120); knowledge sharing (Moser, 2017); and the paradox of power (Bonaccio & Dalal, 2006; Tost et al., 2012).

3.1.2 A consideration of the leadership challenges in combination with the characteristics of servant leadership indicates that a technical expert’s leadership challenges as a manager may be effectively resolved or mitigated by the technical expert adopting a servant leadership style (Table 1). As far as could be established, research has not explicitly explored the application of servant leadership by technical experts as managers as a possible way to address the leadership challenges they may experience. However, servant leadership by technical experts as managers may be efficient in supporting experts to become more effective leaders to the benefit of the organisation (Ghosh, 2013; Greenleaf, 1998: 123; Katou, 2015; Stone et al., 2004; Van Dierendonck, 2011; Wiseman, 2017: 1–32); subordinates

(Greenleaf, 1998: 7; Reinke, 2004; Van Dierendonck, 2011); and the technical expert him or herself (Frankl, 2008: 114–5; Hall et al., 2004).

3.1.3 Certain factors may make it either easier or harder for technical experts to be servant leaders. Some factors evident in the literature that can make it easier include:

- their credibility, authority, and status (Goodall, 2010);
- a legacy motive (Fox et al., 2015); and
- their familiarity with ethical codes (Parris & Peachy, 2013).

3.1.4 Factors that can make it harder for technical experts to be servant leaders include:

- a higher cognitive effort to apply interpersonal leadership skills (Kahneman, 2011: 59–70; Taylor & Benbow, 2016);
- their reliance on personalised power and a higher power distance to subordinates (Sousa et al., 2022; Spreier et al., 2017);
- being perceived as less humble (Rego et al., 2018); and
- experts do not generally ask for leadership development assistance (Gordon, 2020).

3.1.5 The focus of this research is to explore possible leadership challenges of technical experts as managers and how servant leadership can assist experts in improving their leadership effectiveness for the benefit of the organisation, subordinates, and the technical expert him or herself.

3.2 Research objectives

3.2.1 The main aim of this study is to explore how a servant leadership style can assist technical experts in becoming more effective leaders in their respective management positions. In the endeavour to achieve the main research objective, the following secondary research objectives were stated:

- Explore the leadership challenges that technical experts who are managers experience.

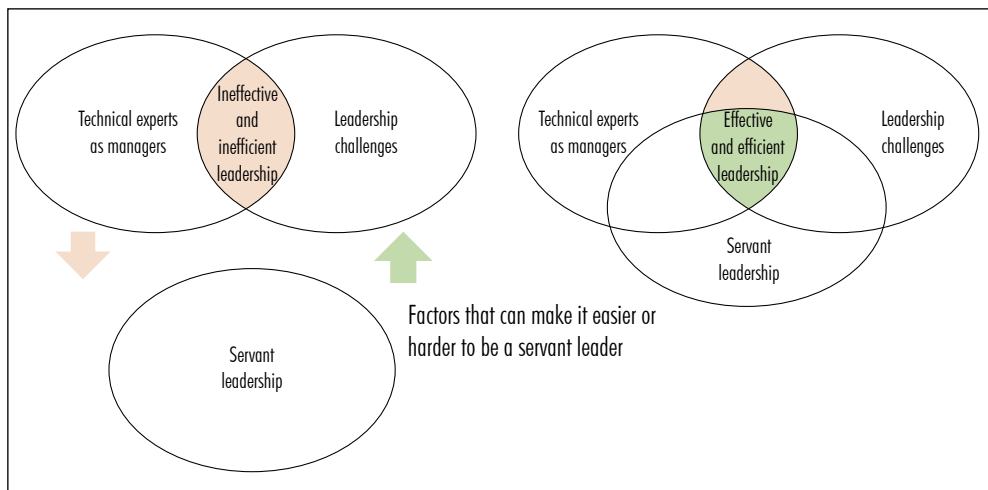


FIGURE 1. Visual illustration of the research focus and the secondary research objectives

- Explore the factors that make it harder or easier for a technical expert to be a servant leader.
- Investigate to what extent servant leadership can be relevant to technical experts who are managers to improve leadership efficiency.

4. RESEARCH METHOD

4.1 Research design and the measuring instrument

4.1.1 Primary qualitative data was gathered through semi-structured interviews to achieve the research objectives. A semi-structured interview is pre-planned and systematic; this structure helps meet the research objectives (Olsen, 2012: 33–8). Although semi-structured interviews are time-consuming and labour-intensive, the interviews offer a valuable opportunity to access independent thoughts through open-ended follow-up questions in a confidential and psychologically safe space with a knowledgeable interviewer (Adams, 2010).

4.1.2 The semi-structured interviews were conducted in two phases. The first phase was conducted with subordinates of technical experts who are managers, and the second phase was with technical experts as managers. The subordinates in the first phase were independent and did not report to any of the managers interviewed in the second phase. The two phases assisted the researcher in exploring the research objectives from the perspectives of subordinates reporting to technical experts as managers and from technical experts as managers themselves. Interview guides were prepared separately for the technical experts as managers (phase two) and subordinates (phase one).

4.1.3 PHASE 1: SEMI-STRUCTURED INTERVIEWS WITH SUBORDINATES OF TECHNICAL EXPERTS AS MANAGERS

4.1.3.1 Interviews with subordinates were included to obtain a balanced perspective and to mitigate the effect of overconfidence and social desirability biases that may occur in the interviews of the managers. Overconfidence and social desirability biases are common when one's image is at stake (Grossman & Owens, 2012). Therefore, the interviews with the subordinates of technical experts occurred first, giving the researcher more insight into leadership challenges experienced by the subordinates of technical experts before the interviews with the technical experts as managers. In addition, this order of the interviews gave the researcher more context and enabled her to ask useful follow-up questions.

4.1.3.2 An overview of the broad interview framework is set out in Figure 2. As per box 2(a), the interview started with the leadership challenges that the subordinates of a technical expert experience from their perspective. The order of questions in the interview is important to mitigate the possibility of earlier questions influencing participants' responses to questions that follow. A recency bias—a tendency to base thinking or answers on what was recently heard (Philips-Wren et al., 2019)—was mitigated by not starting with questions about servant leadership. Next, as per box 2(b), the researcher asked questions to explore the presence or absence of leadership challenges, as identified in the literature.

4.1.3.3 As per box 2(c), following the discussion about the leadership challenges experienced, the researcher asked questions to gauge the servant leadership characteristics of the subordinate's manager. A servant leadership questionnaire by Liden et al. (2008)

was utilised to inform the interview questions. The servant leadership questionnaire is a multidimensional measure of servant leadership and originally had twenty-eight questions measuring seven major dimensions of servant leadership. The key dimensions include conceptualising, emotional healing, putting followers first, helping followers grow and succeed, behaving ethically, empowering, and creating value for the community.

4.1.3.4 The Liden servant leadership questionnaire was originally generated using student data, but the results of an organisational sample validated it. Liden et al. (2008) assessed the relationship between servant leadership and relevant organisational outcome variables using data from subordinates and supervisors. The compilation and validation of the servant leadership questionnaire by Liden et al. (2008) made the questionnaire credible and trustworthy to use as a basis for developing interview questions.

4.1.3.5 Next, as per box 2(d), the interview explored from the subordinate's perspective whether a servant leadership style can help to address the specific leadership challenges experienced. Finally, as per box 2(e), some factors that can make it easier or harder for a technical expert to be a servant leader, as identified in the literature, were discussed.

4.1.4 PHASE 2: SEMI-STRUCTURED INTERVIEWS WITH THE TECHNICAL EXPERTS AS MANAGERS

4.1.4.1 The interviews with technical experts as managers occurred second. The broad interview framework is set out in Figure 3. The semi-structured interviews in phase two

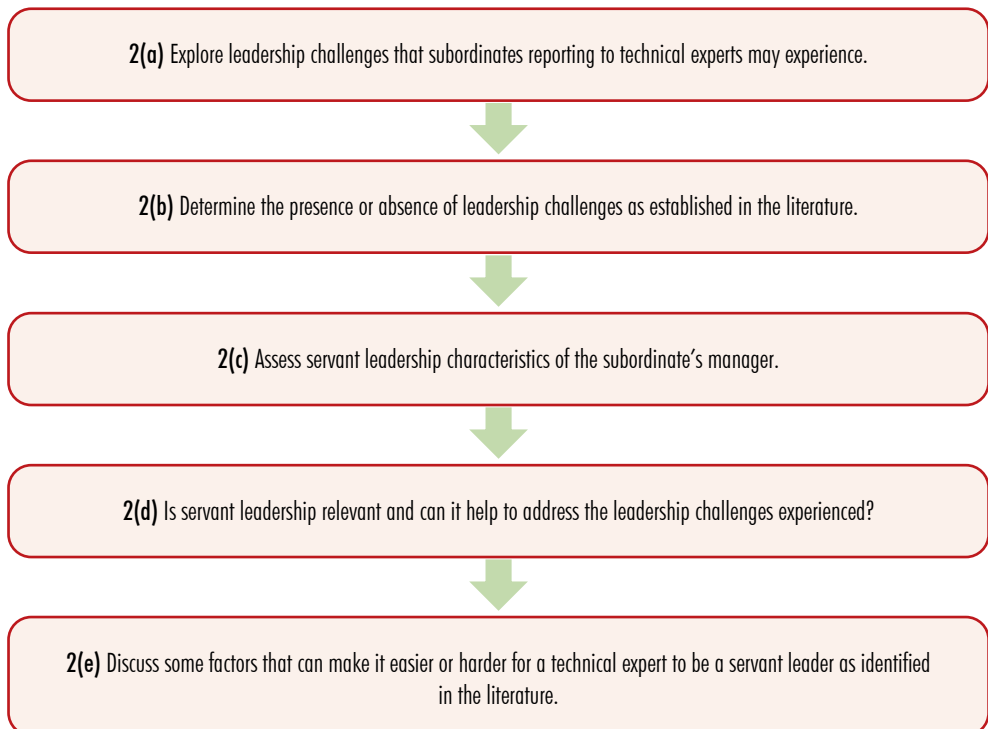


FIGURE 2. Interview framework for the subordinates of technical managers as experts

followed a similar order to phase one for similar reasons. As per box 3(a), the interview with the technical experts as managers started with the leadership challenges that the technical expert as manager experienced from their perspective. Next, as per box 3(b), questions were asked to explore the presence or absence of the leadership challenges identified in the literature.

4.1.4.2 As per box 3(c), the interview continued to explore whether servant leadership can be helpful in addressing the specific leadership challenges experienced in their managerial positions. Next, as per box 3(d), the interview explored which factors make it either easier or harder for the technical expert to be a servant leader. Finally, as per box 3(e), the factors that made it either easier and harder for a technical expert to be a servant leader, as identified in the literature, were explored.

4.2 Sampling and data collection

4.2.1 For the purpose of this research, the target population for the first phase included subordinates of technical experts as managers, and the target population for the second phase included technical experts in managerial positions. The subordinates in the first phase were independent and did not report to any of the managers interviewed in the second phase. Technical experts and subordinates within the actuarial, accounting, and legal

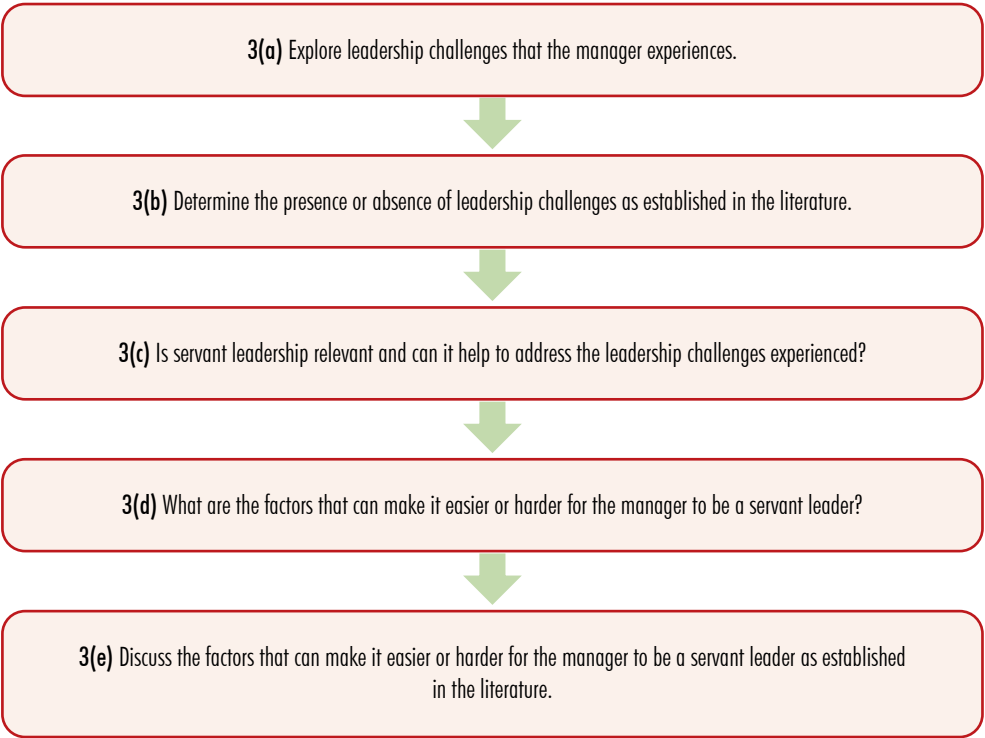


FIGURE 3. Interview framework for the technical managers as experts

professions were deliberately approached and asked if they were willing to participate in their personal capacity. The semi-structured interviews were about one hour for each participant and covered about 12 to 15 questions. One hour was considered a reasonable maximum length for semi-structured interviews to minimise fatigue for both the interviewer and the respondent (Adams, 2010).

4.2.2 The potential participants were professional contacts of the researcher for whom contact details were already available. The researcher had no authority over the potential participants and no material personal affiliation to the potential participants to mitigate conflict of interest and uphold the credibility and trustworthiness of the research. A non-probabilistic availability sample of eight technical expert managers and eight subordinates was selected based on a fit-for-purpose approach to allow the research objectives to be explored (Emmel, 2014: 45–66). The benefits of non-probability sampling include requiring the least time, money, resources, and skills (Daniel, 2012: 82–90). However, non-probability purposive sampling can lead to assumptions and the inappropriate generalisation of the population (Etikan & Bala, 2017).

4.2.3 The risk of inappropriate generalisation can be mitigated if the researcher is objective, open to the participants' perspectives, and attentive to the data, by recording the data exactly as it is said by the participants. This is important in social science research methodology (Ezzy, 2010). The interviews were conducted virtually on Microsoft Teams and recorded. After an interview, the recording was transcribed using the software, Sonix.

4.3 Data analysis

4.3.1 Qualitative analysis of the interview data was done using thematic analysis. Thematic analysis principally focuses on identifying, organising, and interpreting themes from the data (King & Brooks, 2018: 219–33). Themes are defined as recurring and distinctive features in the participants' responses that the researcher sees as relevant to the research objectives (King & Horrocks, 2010: 150). Template analysis, a generic style of thematic analysis not tied to a particular philosophical position (King & Brooks, 2018: 219–33), was used. Template analysis is a structured approach with procedural steps of analysis that can be used to define and organise themes from the interview data.

4.3.2 The first step in template analysis is to become familiar with the data to be analysed. The researcher conducted the interviews and was, therefore, already familiar with the data after the interviews were concluded. Next, the researcher did a preliminary coding of the interview data of four interviews at a time. The researcher did the thematic analysis manually using Microsoft Excel. Every section of the text that offered something relevant to the understanding in relation to the research objectives was highlighted, with a note that included a short code title. The next step towards developing the initial template was to group the preliminary codes into meaningful clusters. After preliminary coding of the first four sets of interview transcripts, the researcher compiled an initial template version. The template identified broader themes within which narrower themes nested. This process was done iteratively and systematically. The template was modified and developed after each set of four interview transcripts had been analysed until the researcher was convinced that the

template offered a rich and comprehensive interpretation of the data. The researcher used the final template to make a definitive interpretation of the data before writing the research results (King & Brooks, 2018: 219–33).

4.4 Ethical considerations

4.4.1 Ethical considerations are important to protect the rights of the research participants and maintain the research's credibility and trustworthiness. Therefore, interviews with participants only proceeded once informed consent had been received in writing, explaining the purpose, benefits and risks of the study. The informed consent also explained that the interview would be recorded and how the data would be used and stored until the end of the study, after which it would be deleted.

4.4.2 Participants took part in the research study in their personal capacity, not as an employee of any organisation, and this was confirmed in the informed consent form. Therefore, organisational permission was not required. The interviews were conducted on a confidential basis. The respondents' identity and place of work were not disclosed in the interview results, as that information was not relevant to the research study. When subordinates were interviewed, the name of their manager was kept anonymous. The interviews were conducted outside normal office hours, per agreement with the participants, to maintain confidentiality. In an online environment with virtual interviews, it was also important to ensure that the participants were familiar with and comfortable with the technology used (Engward et al., 2022).

4.4.3 The participants' identities were not disclosed in the research results and were erased from the interview data. Participants were referred to using a coding system, e.g., 'Participant 1_Subordinate'. The principles of respect for and confidentiality of the participants and their contribution were always upheld. All the interview recordings and data are stored securely in OneDrive on a computer with a bit locker code and password. Only the researcher has access to the data.

5. RESEARCH FINDINGS

5.1 Realised sample description

5.1.1 A non-probabilistic availability sample of eight technical experts, and eight subordinates was selected based on a fit-for-purpose approach. The semi-structured interviews were conducted between 5 July and 6 September 2022. Eight subordinates of technical experts were interviewed in phase one, and eight technical experts as managers were interviewed in phase two.

5.1.2 The subordinates in phase one were mostly in middle management, while the level of management for the technical experts as managers in phase two ranged from senior to executive-level management. Most participants (N=13, 81.25%) were in the actuarial profession. Two participants (N=2, 12.5%) were in the legal profession, and one was in the accounting profession (N=1, 6.25%). Eleven participants were male, and five were female (68.75% male, 31.25% female). A detailed breakdown of the descriptive factors of the research participants is provided in Table 2 for phase one and Table 3 for phase two.

TABLE 2. Research participants in phase one

Subordinates that report to a technical expert			
Industry	Current job title	Sex	Years of work experience
Actuarial	Actuarial manager	Male	10 years
Actuarial	Asset liability manager	Male	10 years
Actuarial	Product implementation specialist	Female	30 years
Actuarial	Actuarial specialist	Female	14 years
Legal	Legal and compliance manager	Female	18 years
Actuarial	Business development actuary	Male	8 years
Accounting	Finance manager	Male	13 years
Actuarial	Actuarial analyst	Male	10 years

TABLE 3. Research participants in phase two

Technical experts as managers			
Industry	Current job title	Sex	Years of work experience
Actuarial	Head: Pricing	Male	16 years
Actuarial	Senior manager	Female	16 years
Actuarial	Pricing actuary	Male	15 years
Actuarial	Actuarial expert	Male	7 years
Actuarial	Pricing actuary	Male	17 years
Legal	Legal executive	Male	20 years
Actuarial	Head: Group insurance	Male	17 years
Actuarial	Actuary	Female	15 years

5.2 Key themes and sub-themes from the thematic analysis

The key themes and sub-themes from the thematic analysis were identified from the interviews (Table 4). The themes and sub-themes are interdependent and not neatly separable, and overlap in discussion is unavoidable.

5.3 Theme 1: Leadership challenges that technical expert managers may experience

5.3.1 SUB-THEME 1.1: TECHNICAL EXPERT MANAGERS STRUGGLE TO RELATE TO SUBORDINATES ON A HUMAN LEVEL

5.3.1.1 A strong theme that could be identified from both the subordinates' and technical expert managers' perspectives is that technical expert managers struggle to relate to subordinates on a human level. Subordinates may experience a disconnect with technical expert managers and difficulty in building a relationship beyond a formal work relationship. Technical experts may find it harder to show empathy and sympathy.

TABLE 4. Key themes and sub-themes from the thematic analysis

Key themes	Sub-themes
Leadership challenges that technical expert managers may experience	1.1 Technical expert managers may struggle to relate to subordinates on a human level 1.2 Technical experts are open to listening to alternative views and opinions, but there may be resistance to accepting alternative views 1.3 Technical expert managers struggle with delegation and limited time capacity, which makes people management difficult 1.4 Egocentric thinking may present a leadership challenge for technical experts as managers 1.5 Technical expert managers may have limited influence higher up in the hierarchy, which may limit exposure and development opportunities for their subordinates
Factors that make it easier for technical experts as managers to assume a servant leadership style	2.1 Emerging technical experts look for a technical expert as a leader 2.2 The legacy motive for many technical experts goes beyond just making a difference on a technical level to having an impact on people 2.3 Servant leaders create servant leaders 2.4 Organisational culture and where the organisation is in its growth cycle can either make it easier or harder for managers to assume a servant leadership style 2.5 Interpersonal and leadership skills improve with experience
The relevance of servant leadership for a technical expert as manager	3.1 If the organisational objectives are met, everyone benefits 3.2 You need people to carry the organisation forward

... but I never really developed that personal connection with him ... because he was just a little bit robotic. So, he's definitely trying, but it almost feels forced, you know? (P6_Subordinate)

Just that thing of relating to people. Right, so actually it's showing empathy and sympathy and just relating because you often just think in technical terms and not thinking that there is a person also that you're dealing with. (P8_Technical expert as manager)

5.3.1.2 The consequences of technical expert managers' inability to relate or build stronger relationships with subordinates include poor communication and information sharing. In addition, managers may not know what motivates subordinates, particularly subordinates who don't have the same technical background as the technical expert manager. Often, subordinates may take it upon themselves to manage and motivate the team on behalf of the technical expert manager.

There is probably some evidence that technical experts tend to be less people-savvy. So, I wouldn't necessarily say that I am completely obtuse to interacting with people, but I think understanding or learning to understand that sometimes the way I think about some of the things that motivate me are very different to the general person, especially non-technical people, and learning how to channel that and be more empathetic, sometimes create[s] a bit of a block. (P3_Technical expert as manager)

... but they are a poor manager, and then you end up having to manage your own team anyway and undo a lot of the damage that they are doing. (P5_Subordinate)

5.3.1.3 The challenge in relating to subordinates was not because of hierarchical matters, as most participants indicated that their relationship with their technical expert manager was on equal footing. So, the study did not indicate high power distance relationships as one may expect (Issac, 2022). Rather, the findings under sub-theme 1.1 indicated that technical experts as managers might experience interpersonal leadership challenges that can hinder effective leadership. The findings relating to the interpersonal leadership challenges align with previous research on soft skills shortage and a less developed relationship domain (Gordon, 2020; Joseph et al., 2010; Taylor & Benbow, 2016).

5.3.1.4 Given the interpersonal leadership challenges that technical expert managers experience and the finding that technical expert managers struggle to relate to subordinates on a human level, there is not a strong indication that technical expert managers generally adopt a servant leadership style. Servant leaders tend to operate from a stronger relationship domain because they generate high levels of trust, show concern for others, and communicate and listen well (Reinke, 2004; Stone et al., 2004). Servant leaders have an interpersonal accepting attitude that creates a safe and trusted psychological climate (Reinke, 2004; Van Dierendonck, 2011).

5.3.2 SUB-THEME 1.2: TECHNICAL EXPERTS ARE OPEN TO LISTENING TO ALTERNATIVE VIEWS AND OPINIONS, BUT THERE MAY BE RESISTANCE TO ACCEPTING ALTERNATIVE VIEWS

5.3.2.1 Most of the subordinates and the technical expert managers themselves confirmed that technical experts as managers were open to listening to alternative views and opinions; however, there was some evidence of resistance to accepting alternative views and opinions.

I think we understand the same problem in a different way, but he is just stuck in what he sees. (P3_Subordinate)

So as an example, they might ask for opinions, but just for the sake of asking opinions where the decision sometimes feels like it was already made. That's probably the bulk of my experience. (P8_Subordinate)

5.3.2.2 Managers' behaviour in being open to listening to alternative views and opinions may indicate that they are aware that it is important to consider employees' voices. However, the resistance to accepting alternative views that subordinates perceived doesn't provide confidence that technical expert managers truly value that balanced information processing, obtaining broader perspectives and differing opinions can improve their decision-making (Larrick, 2009; Rego et al., 2018). This finding of resistance to accepting alternative views offers evidence that the paradox of power may be a leadership challenge for technical expert managers and that they may underutilise the intelligence around them, which leads to leadership inefficiency. The paradox of power relates to decision rights being coupled with the power-induced neglect of the judgement of others and that advice from others may be undervalued and own opinion overvalued (Bonaccio & Dalal, 2006; Tost et al., 2012). Therefore, accepting alternative views and opinions by technical expert managers may be situational.

... it also depends on how convinced I am of what I was thinking..., as well as the credibility that the other person has. (P1_Technical expert as manager)

... but I also guess it depends on how comfortable I feel with the topic and how convinced I am of my own opinion. (P2_Technical expert as manager)

5.3.2.3 Accepting alternative views seems to depend on how convinced or comfortable a technical expert manager is with the topic. So, in their area of expertise, technical expert managers may struggle most with the paradox of power as a leadership challenge.

5.3.3 SUB-THEME 1.3: TECHNICAL EXPERT MANAGERS STRUGGLE WITH DELEGATION AND LIMITED TIME CAPACITY, WHICH MAKES PEOPLE MANAGEMENT DIFFICULT

5.3.3.1 Clearly, most technical expert managers struggled with limited time capacity because they had to attend to technical matters and manage people. However, the challenge of limited time capacity may be exaggerated by inadequate delegation. A lack of delegation by technical expert managers can limit subordinates' growth. In addition, many technical experts are task-driven and prefer technical work that may further contribute to them not delegating tasks adequately to their subordinates.

So, everyone is just, I guess, stretched to the max in terms of getting to everything ... And I think that's what happens to me when I'm under pressure, I just want to get the stuff done. (P2_Technical expert as manager)

So, I think there's an element of insecurity from the senior manager's perspective in terms of delegating responsibilities and empowering his direct reports, which then kind of flows through to my level, unfortunately. (P8_Subordinate)

5.3.3.2 During training and development from an early age, technical experts learn to become self-reliant and to perform as individuals. Therefore, letting go of control, collaboration, and developing interpersonal skills as a manager later in their careers, may require more effort. A further consequence of limited time capacity among technical experts is that there may be a lack of mentorship for the technical expert as a leader. This is unfortunate because servant leaders create servant leaders (Greenleaf, 1998: 123).

I feel like I need more mentoring, actually, but there's less time for it, you know? (P2_Technical expert as manager)

5.3.3.3 On the other hand, limited time capacity may encourage technical expert managers to share more knowledge and hand over matters to emerging technical experts to lighten their workload. In addition, a paradoxical finding of the study was that most technical expert managers were willing to share their knowledge with no evidence of resistance to protect their competitive advantage.

But I've found that if you are willing to share and to train and upskill, your opportunities tend to be more, not less. The people in leadership positions above you take note of the fact that

you share your skills and are good at upskilling those around you, and therefore, they create leadership opportunities for you in which you can do that.

(P1_Technical expert as manager)

5.3.3.4 Benefits of sharing knowledge and delegating adequately to subordinates are that technical expert managers have more time for people management and development of strategies to impact business growth positively, leading to better leadership efficiency.

5.3.4 SUB-THEME 1.4: EGOCENTRIC THINKING PRESENTS A LEADERSHIP CHALLENGE FOR TECHNICAL EXPERTS AS MANAGERS

5.3.4.1 Many subordinates indicated that it seems difficult for the technical expert as manager to understand or consider a matter from another's perspective. Egocentric thinking refers to a cognitive bias in that the technical expert manager would assume that others share the same perspective they do. This assumption may stem from a knowledge gap, where the technical expert assumes that the subordinate has a similar level of knowledge on a particular topic. It may also relate to not looking at a problem from the same reference point, for example, from a theoretical and not from a practical perspective.

They expect everybody to know what they've collected over the years. (P2_Subordinate)

I think it is maybe that leader does really understand the technical aspects, but he does not understand how to make it practical in a practical environment. (P3_Subordinate)

5.3.4.2 Egocentric thinking may also make it difficult for a technical expert manager to manage, communicate and collaborate with subordinates from different professional backgrounds. In this scenario, the technical expert manager cannot be self-reliant, and it is important to utilise the intelligence around them.

Where I think I've struggled as well is where people are reporting to me from a different profession. (P3_Technical expert as manager)

5.3.4.3 At the highest level of moral cognitive development, mutual respect and imagining how things look from another person's perspective become part of the decision-making and reasoning process (Kohlberg & Kramer, 1969). So, to manage people unassumingly while being aware of potential biases that one may have requires development.

5.3.5 SUB-THEME 1.5: TECHNICAL EXPERT MANAGERS MAY HAVE LIMITED INFLUENCE HIGHER UP IN THE HIERARCHY, WHICH MAY LIMIT EXPOSURE AND DEVELOPMENT OPPORTUNITIES FOR THEIR SUBORDINATES

5.3.5.1 Some subordinates noted that technical experts as managers seem to have limited influence higher up in the hierarchy. This may be because technical expertise is seen more as an input to business decision-making rather than a driver for decision-making.

The feedback gets taken and then given to the higher powers. But then, yeah, in terms of her influence there, I'm not too sure. (P1_Subordinate)

People that know the business might have a little bit more influence than technically focused people that have the answers. So, the technical expertise is seen more as an input to decision-making than a driver for decision-making, if I can put it that way. (P8_Subordinate)

For a lot of my managers over the years, I think they also didn't have that power to really go and find out what they can do or what they can change. (P6_Subordinate)

5.3.5.2 Subordinates felt that if their technical expert manager had limited influence higher up in the hierarchy, it might limit their exposure to higher levels in the business. As a result, subordinates may miss further growth opportunities beyond their area of expertise, such as strategy, business administration and management. The perception of technical experts that business holds and their involvement in only technical matters can be a negative reinforcing cycle that presents a leadership challenge to technical expert managers, which can also be to the detriment of their subordinates' growth and empowerment.

I think I might not get the exposure that I could get, or I might not be involved in certain conversations where I could be ... So, it's just this perception of what my skills are, and my skills are only this, that could play a part in that as well. (P8_Subordinate)

So, there's definitely still some of that as a challenge that technical managers will face as they come in, and people have a preconceived idea of what they're supposed to be.

(P1_Technical expert as manager)

5.3.5.3 A less developed relationship domain and challenges with interpersonal skills may make it harder for technical experts to manage upwards, challenge the stereotype of a technical expert, and achieve more influence higher up in the hierarchy (Gordon, 2020).

5.3.6 CONCLUDING REMARKS – THEME 1

5.3.6.1 The findings of sub-themes 1.1 to 1.5 identified leadership challenges that technical expert managers may experience. Most of the leadership challenges can be linked to challenges experienced in the interpersonal domain, like struggling to relate to subordinates on a human level, egocentric thinking, the paradox of power that results in a resistance to accepting alternative views and difficulty with having influence higher up in the hierarchy.

5.3.6.2 The findings align with research indicating that technical expert managers may experience interpersonal leadership challenges that can hinder effective leadership. As shown in the literature review, previous studies indicated that although experts tend to be strong in the technical domain, they often struggle in the relational domain (Gordon, 2020). The findings thus confirm that technical expert managers struggle to relate to subordinates on a human level. The finding of the paradox of power that results in resistance to accepting alternative views aligns with previous research indicating that a technical expert has expert power that may often lead to overconfidence and inhibits advice-taking (Tost et al., 2012).

5.3.6.3 The findings of technical experts' egocentric thinking and their difficulty in influencing managers higher up in the hierarchy were new challenges highlighted by

this research study, which were not previously identified in the literature review. A further challenge not identified in previous research is that technical expert managers often struggled with limited time capacity due to a lack of delegating technical work or projects.

5.3.6.4 This study showed no evidence of the leadership challenge of limited knowledge sharing by technical expert managers. Previous research noted that experts face a conflict of interest in knowledge sharing in that from a social or collective perspective, experts should share their knowledge, but individually, they are better off not doing so because acquiring knowledge is costly, and they would give up their competitive advantage (Moser, 2017). In contrast, most of the participants in this study indicated that technical expert managers are very willing to share their knowledge.

5.4 Theme 2: Factors that make it easier for technical experts as managers to assume a servant leadership style

Participants noted many factors that make it easier for a technical expert as a manager to assume a servant leadership style. The sub-themes below describe factors that have been repeatedly mentioned.

5.4.1 SUB-THEME 2.1: EMERGING TECHNICAL EXPERTS LOOK FOR A TECHNICAL EXPERT AS A LEADER

5.4.1.1 Some of the subordinates interviewed are emerging technical experts who confirmed that they valued having a technical expert as a manager in their specific field of expertise. Subordinates want access to the technical expert's knowledge, skill, and experience. On the path towards a professional qualification, technical expert managers can offer valuable guidance and mentorship to emerging technical experts. Technical expert managers in the same field of expertise may also have a better understanding of what it takes to achieve a specific qualification and can, therefore, provide better moral support to emerging technical experts.

It helps because I get exposure to that knowledge and skills. (P4_Subordinate)

So, with us being in a very technical environment. I think a lot of the time, you also expect to learn a lot from your manager in that sense. (P8_Subordinate)

5.4.1.2 Therefore, subordinates are more willing to follow the leadership of the technical expert manager, and, in turn, the technical expert manager's credibility will positively impact their influence as a leader. Technical expert managers may also be able to relate better to subordinates in the same field of expertise, which will support better working relationships.

I think the better expertise you have, the more you're able to influence, actually. (P5_Subordinate)

5.4.1.3 Most of the subordinates noted that the technical experts are always willing to help and to share knowledge and that their managers rather provide guidance than a full

solution when they require assistance. Most subordinates also felt they had accountability and responsibility for their role. In this sense, the technical expert managers do not foster dependency on themselves but rather empower and develop emerging technical experts.

5.4.2 SUB-THEME 2.2: THE LEGACY MOTIVE FOR MANY TECHNICAL EXPERTS GOES BEYOND JUST MAKING A DIFFERENCE ON A TECHNICAL LEVEL TO HAVING AN IMPACT ON PEOPLE

5.4.2.1 It was clear that not many technical expert managers have thought about their legacy motive, i.e., what they want to be remembered for when they retire. But, interestingly, almost all the technical expert managers described their legacy motive as wanting to make a difference beyond just the technical work they deliver or just meeting organisational objectives to having a bigger impact on people.

You don't remember the work necessarily, but you remember the feeling that you had with people and that connection. So, I think it's just making that connection and really being known for [*sic*] someone who's there for you when you need me. (P2_Technical expert as manager)

I want to be remembered as someone who was able to empower people. I want someone to say I am who I am because I had this great manager who inspired me and gave me the tools to be the person I am. (P6_Technical expert as manager)

5.4.2.2 Ironically, the interviews often revealed that the technical expert managers currently spend most of their time on technical work instead of people management, ie. their activities are not aligned to what they need to do to achieve their stated legacy motives.

It was quite interesting to explore your legacy motive versus what you're currently doing and just realising how disjointed it is. (P2_Technical expert as manager)

5.4.2.3 Technical expert managers' legacy motives may encourage them to lean more towards a servant leadership style.

5.4.3 SUB-THEME 2.3: SERVANT LEADERS CREATE SERVANT LEADERS

5.4.3.1 Some technical expert managers indicated that they were fortunate to learn from other servant leaders, like previous managers or even their parents, making it easier for them to assume a servant leadership style. The example of a servant leader allows for first-hand experience of the benefits of servant leadership, which inspires subordinates to be servant leaders. Managers that consider their subordinates' best interests build trust and respect and improve loyalty toward them, which benefits the manager and the organisation.

I think what has made it easy is I've definitely had leaders whom I would call servant leaders. I think I've been very fortunate. Yeah. I've been lucky in that those have been the leaders that have impacted me the most. (P3_Technical expert as manager)

I actually learned it from my parents. I feel my parents were servant leaders, but I didn't understand it at that stage. (P5_Technical expert as manager)

5.4.3.2 Servant leaders create servant leaders. A servant leader leads by example through their behaviour and by inspiring others to do the same. The opposite also holds, in that poor behaviour by management can inspire others not to adopt the same leadership style.

I did try to resign last year because I was not happy with the way a specific manager was treating my subordinates. (P5_Technical expert as manager)

5.4.3.3 Another interesting perspective was that the younger generation, or the millennials, are purpose-driven and look for leadership as a relationship in the workplace.

So, for the millennials, questions in terms of why we're doing things and what we're helping with becomes important ... We want to be in an enjoyable environment where we can trust people. More of a family environment rather than feeling like we're working in a factory ... But yes, I think if I had someone like my current manager very early on in my life, I probably wouldn't have jumped ship as much as I did. (P8_Subordinate)

5.4.3.4 The purpose-driven mindset of millennials and how they view the importance of relationships in the workplace may make servant leadership more relevant and can help to reduce turnover. Therefore, one may also be able to say that those who value servant leadership also seek servant leaders.

5.4.4 SUB-THEME 2.4: ORGANISATIONAL CULTURE AND WHERE THE ORGANISATION IS IN ITS GROWTH CYCLE CAN EITHER MAKE IT EASIER OR HARDER FOR MANAGERS TO ASSUME A SERVANT LEADERSHIP STYLE

5.4.4.1 From the findings, it was clear that organisational culture can either be supportive or not of managers assuming a servant leadership style. In addition, organisational culture influences the power distance relations between staff or where the primary focus of managers lies, e.g., on the organisation's objectives or the staff's well-being and growth.

Our organisational culture is very supportive, especially being in an actuarial community. There's a lot of things that's been in place for many years, and it's well developed to actually ensure that people do grow. (Participant 8_Technical expert as manager)

If the culture does not come from the top, it's going to be very difficult to assume a servant leadership style. (Participant 5_Technical expert as manager)

5.4.4.2 Another influence on how easy or hard it is to assume a servant leadership style is where a business is in the growth cycle. Typically, managers in younger or start-up businesses find it harder to assume a servant leadership style because focusing on achieving business sustainability may mean less time to spend on the people management side.

So, I myself am in the start-up environment. It definitely is more difficult to balance what I need to do immediately with having critical conversations with subordinates. However, the fact is that if a person leaves, that's a whole loss of IP. (P3_Technical expert as manager)

If you all of a sudden double in size, it really makes a difference ... We've had a lot of work so we could employ more people. But it's almost like that rat race of trying to stay ahead, and we probably didn't spend enough time on the softer management side.

(P2_Technical expert as manager)

5.4.4.3 An important consequence of servant leadership in an organisation is that it can bring about deep change, which can extend to a positive impact on customer service.

Focusing as well on what impact I can have on people's lives through the solutions I offer to the company and through the company to the industry. (P1_Technical expert as manager)

5.4.4.4 Organisational culture can influence how easy or hard it is for the technical expert manager to adopt a servant leadership style: on the other hand, servant leadership can also influence organisational culture, for example, by encouraging client centricity. It can be a virtuous cycle.

5.4.5 SUB-THEME 2.5: INTERPERSONAL AND LEADERSHIP SKILLS IMPROVE WITH EXPERIENCE

5.4.5.1 Often technical experts are promoted into leadership roles due to their technical expertise but without leadership development. The technical expert manager may experience leadership challenges to the detriment of the organisation, their subordinates, and themselves.

I was put into that role purely because I had technical skills, but then definitely I didn't have managerial skills, you know, so that was a challenge ... It used to cause anxiety in my life. Right, that I would want to run away from the job. (P6_Technical expert as manager)

5.4.5.2 Technical experts as managers could improve their interpersonal skills with experience to the point that some managers now consider their leadership skill as their competitive advantage in a technically orientated environment. In response to the question of whether technical or interpersonal skills come more easily to them, several of the technical experts as managers concluded that although technical skills came more easily at the start of their careers, with more leadership experience, interpersonal skills come more easily.

Over a period of time, with experience, I evolved and got better. But then I have to say, it was self-taught. (P6_Technical expert as manager)

I want to believe my technical skill, but I think more recently, probably more the interpersonal skill. I think it's changed, and I think I've changed over the years.

(P8_Technical expert as manager)

Probably the interpersonal skills. It's what I've been doing more of for the last couple of years.

(P7_Technical expert as manager)

5.4.5.3 Evidently, interpersonal and leadership skills can be developed and improved. Technical expert managers can avoid the Peter Principle and grow into their roles

as influential leaders. Practice-based experience seems most efficient in enhancing leadership skills, but it may take a long time. Methods to accelerate experience-based learning will be beneficial for technical expert managers. One way to do so may be through mentorship by more experienced technical expert managers.

It becomes very difficult for you to be a leader and at the same time be that technical person. Right. Unless someone takes you under their wing and they train you to be a leader.

(P6_Technical expert as leader)

5.4.5.4 Technical experts can add significant value as managers and leaders in their field of expertise. In addition, leadership development, experience and mentorship can assist in achieving better leadership efficiency.

5.4.6 CONCLUDING REMARKS – THEME 2

5.4.6.1 The findings of sub-themes 2.1 to 2.5 identified factors that make it easier for technical experts as managers to assume a servant leadership style. Emerging technical experts look for a technical expert as a leader. This finding aligns with previous research noting that status and credibility can enhance a leader's power and influence (Goodall, 2010). Remarkably, and in contradiction to previous research, there was no indication that subordinates experienced dependency-orientated help where technical expert managers only offer quick answers or complete solutions instead of guiding them towards finding solutions themselves (Alvarez & Van Leeuwen, 2011; Quinn, 1996: 115–20). There was no evidence that the technical expert managers' high expert power caused them not to be perceived as humble (Rego et al., 2018). Therefore, humility and integrity further supported the technical expert managers' positive influence as leaders.

5.4.6.2 The legacy motive for many technical experts went beyond just making a difference on a technical level to having an impact on people. The legacy motives of the technical expert managers align with previous research stating that a legacy motive can provide a link to a life-meaning motivation such as having the desire to have a positive effect on others and leaving the world a little better off for their presence in it (Fox et al., 2015). Technical experts as managers offer significant promise to be impactful leaders. The effects on social and human capital, driven through their legacy motive, can benefit technical expert managers by positively influencing their leadership reputation (Hall et al., 2004).

5.4.6.3 The example and influence of servant leaders extends further by encouraging their subordinates to adopt a servant leadership style. The finding aligns with Greenleaf's theory that servant leaders create servant leaders (Greenleaf, 1998: 123). Subordinates who value servant leadership may also seek other servant leaders to work for. The study supported previous research on how a culture of empowerment and servant leadership can help mature organisations to maintain employee satisfaction (Smith et al., 2004). However, participants also referred to the difficulty of applying servant leadership in a fast-growing organisation. Previous research noted that in a start-up or growing organisation, spending more time on subordinates' growth may lead to a decrease in the expert's required level of performance (Hinds & Pfeffler, 2003).

5.4.6.4 There was strong evidence that with time and experience, the interpersonal skill or servant leadership capability of technical expert managers improves, and they become more confident of relying on their interpersonal skills and leadership, and not just their technical skills. They overcome the tyranny of competence with time and experience (Quinn, 1996: 115–20). This finding aligns with research saying that interpersonal skills learning comes from exposure to real-world work situations (Taylor & Benbow, 2016).

5.5 Theme 3: The relevance of servant leadership for a technical expert as manager

5.5.1 SUB-THEME 3.1: IF THE ORGANISATIONAL OBJECTIVES ARE MET, EVERYONE BENEFITS

5.5.1.1 Focusing on organisational objectives is necessary due to business sustainability and growth, meeting deadlines, deliverables, and achieving short-term incentives. There may be competition among leaders. For example, if a leader neglects the organisation's objectives, they may be replaced by somebody who chases and achieves the goals. On the other hand, if the organisational objectives are met, everyone will benefit through financial reward, and business growth may lead to further growth opportunities for staff.

... because if the organisation meets the objectives, it's to the benefit of all the team members.
(P3_Subordinate)

I think management doesn't always have a long-term outlook. They are incentivised for the short term, and they are measured by short-term gains.
(P2_Subordinate)

To actually see the fruits of a servant leadership style is not as immediate, compared to if they focus on the bottom line.
(P5_Subordinate)

5.5.1.2 It was noted that a subordinate or manager's key performance criteria mainly determines which deliverables will receive the most focus, because meeting the key performance criteria will determine how the employee gets financially rewarded. Key performance criteria mostly align with the organisational objectives. Therefore, short-term incentives normally encourage leadership to have more of a focus on organisational objectives versus having a primary focus on their subordinates' growth and development.

5.5.2 SUB-THEME 3.2: YOU NEED PEOPLE TO CARRY THE ORGANISATION FORWARD

5.5.2.1 Organisational objectives will be stifled if subordinates are not encouraged to grow. It is impossible to perform well in an organisation when a team is negative or disengaged. An organisation may also experience high turnover, which can be costly.

But then I think the human factor is important because then you also need people to carry the organisation forward.
(P6_Technical expert as manager)

And one of the things that actually keep[s] your team engaged and happy and motivated and energised is to actually have a focus on their growth and their potential.
(P8_Technical expert as manager)

5.5.2.2 It was noted that managers that put the growth and well-being of their subordinates first get better output from their subordinates, with the potential to exceed the metrics that measure the achievement of the organisational objectives. In the end, the growth of subordinates means that the results will follow, and the organisation can also grow. In addition, developing and empowering subordinates creates space for the manager to grow into other areas, such as strategic thinking.

5.5.2.3 As noted by a participant who works in a consultancy based on billable hours, it may be easier to spend more time on subordinates' growth and development where mentorship is part of a manager's key performance criteria.

So, when you join, and you're a new person, I think 90% of your KPC goes towards how many billable hours have you actually done this year? Have you reached your target? And that decreases as you become more senior. (P2_Technical expert as manager)

He's very good at, let's call it separating manager responsibilities and mentor responsibilities. (P8_Subordinate)

5.5.2.4 Therefore, the benefit of focusing on subordinates' growth and development in the organisation is recognised by technical expert managers. The benefits include a more engaged, productive and satisfied workforce that carries the organisation forward. However, limited time capacity and short-term business priorities can make it difficult to adequately focus on subordinates' growth and development.

5.5.3 CONCLUDING REMARKS – THEME 3

5.5.3.1 Finding 3.1 indicated that participants believe that everyone benefits if the organisational objectives are met. Previous research explains that transformational leadership builds commitment to the organisational objectives and inspires subordinates towards a shared vision (Smith et al., 2004). So, a primary focus on organisational objectives aligns with a transformational leadership style. On the other hand, a focus on meeting organisational objectives must not be to the detriment of subordinates' growth and development. Participants noted, per finding 3.2, that focusing on people is necessary to drive the organisation forward. Previous research explains that a servant leader focuses on subordinates' empowerment and views organisational concerns on a peripheral basis, trusting that organisational results will follow as a secondary outcome (Patterson, 2003; Stone et al., 2004). So, a primary focus on subordinates' growth and empowerment aligns with a servant leadership style.

5.5.3.2 The findings from Theme 3 indicate that the technical expert as manager may experience conflict between meeting the shorter-term business objectives and the longer-term development needs of subordinates. The requirement of a balance in focus between organisational objectives and the empowerment of subordinates may indicate that a balance between a transformational and servant leadership style may be most suitable for technical experts as managers.

6. DISCUSSION

6.1 This research study discussed that many organisations promote technical experts with little or no leadership training or managerial experience. This shortage of leadership development may cause leadership challenges and inefficiency to the detriment of technical experts as managers, their subordinates, and the organisation. From the study's results, several leadership challenges were identified, particularly in the interpersonal domain, which make it harder for technical expert managers to be effective leaders. Servant leadership may assist in mitigating the leadership challenges that technical expert managers experience because a servant leader tends to operate from a stronger relational domain with a primary focus on the well-being and empowerment of subordinates.

6.2 Adopting a servant leadership style may further assist technical expert managers to lead more effectively by encouraging adequate delegation. This will help mitigate the challenge of limited time capacity experienced by technical expert managers, which makes people management difficult. Servant leadership can encourage delegation by technical expert managers because servant leaders strive to provide and delegate stretch assignments to their subordinates to promote their growth and empowerment.

6.3 Several factors have been identified in the research, including paradoxical findings that make it easier for technical expert managers to be impactful servant leaders. These findings indicated there were no high-power distance relationships between technical expert managers and their subordinates; instead, most relationships were on equal footing, and technical experts were very willing to share their knowledge with subordinates. Other factors that make it easier for technical expert managers to be servant leaders include that emerging technical experts look for a technical expert as a manager, and the example set by servant leaders creates more servant leaders. Therefore, the positive impact of servant leadership can be multiplied among technical experts. Technical expert managers are mostly humble and have integrity and, in addition, the ethical code of their professions often supports their integrity and influence as a leader. Lastly, the legacy motive of most technical experts goes beyond just making a difference in the technical area of work to making a positive impact on people.

6.4 Importantly, an organisation's culture and where the organisation is in its growth cycle may or may not support a servant leadership style. Technical expert managers may be conflicted between meeting short-term business objectives and meeting the longer-term growth needs of their subordinates. For example, an organisation in a start-up or growth phase will primarily focus on meeting the organisation's objectives and making the business sustainable. Therefore, a technical expert manager who solely assumes a servant leadership style may fall short. A balance between a transformational and servant leadership style may be most suitable.

7. MANAGERIAL IMPLICATIONS

7.1 As this study has shown, technical experts as managers may experience some leadership challenges in the absence of leadership development or experience, particularly in the interpersonal domain. Organisations often don't have the luxury of adding resources, and better utilising capabilities within the organisation becomes necessary. Helping technical expert managers to become more efficient leaders will benefit organisations. If organisations can improve leadership efficiency, the organisation won't just be an enjoyable place to work but will also gain a competitive advantage. Leadership is a critical force for leveraging the full capability of the organisation.

7.2 Leadership awareness and development for technical experts must start long before they are promoted to managerial level. There are many opportunities for leadership development during the technical expert's education and training. Organisations should encourage learning about leadership models from early education through to tertiary education. Ideally, there must be a healthy balance between theoretical learning and practice-based learning to develop leadership skills because technical expert managers have highlighted the value of practice-based learning. In the workplace, a structure can be implemented to facilitate mentorship, particularly for young leaders. Such structures can also be managed by the governing bodies of professions. Mentorship may assist in accelerating experience-based learning from one technical expert manager to another. It is also suggested that governing bodies of professions, like the Actuarial Society of South Africa or the South African Institute of Chartered Accountants, include leadership alongside ethics as a module in professionalism courses. In their leadership development, it may be helpful for technical experts to apply visionary thinking and define their legacy motive much earlier in their careers, as this may considerably influence their leadership approach.

7.3 The recruitment process in an organisation also has a role to play. An individual must ideally not be promoted into a managerial position without adequate leadership development. This is a virtuous cycle. If technical experts know that leadership development is a prerequisite for certain promotions, they will seek leadership development to be eligible. When a technical expert needs to be promoted without leadership development, organisations must consider how to support the technical expert to avoid the Peter Principle. A human resource or organisational development function can support the technical expert as a manager with coaching, leadership training and interpersonal skill development.

7.4 Technical expert managers may experience a conflict between meeting shorter-term business objectives and the longer-term growth needs and ambitions of subordinates. Organisations can assist technical expert managers by appropriately structuring their key performance metrics to include an allocation towards subordinates' growth. A leader's success must be tangibly measured by their subordinates' growth and performance. Structuring the technical expert's key performance metrics adequately between technical work and people management responsibilities will assist in managing their limited time capacity optimally.

8. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

8.1 The study had some limitations and future research possibilities. Firstly, most of the participants in the study were from the actuarial profession, which has a lower female representation. Therefore, future research may be conducted to broaden the scope to include more professions and measure differences between females and males when assessing servant leadership characteristics.

8.2 A qualitative study was done using semi-structured interviews. A wider audience of technical expert managers can be reached through a quantitative research study on the specific findings of this qualitative research study. Secondly, several other aspects could influence the efficiency of the leadership of technical expert managers. For example, personality preferences or organisational culture. Research is recommended to differentiate between alternative causes of leadership inefficiency among technical experts as managers.

8.3 Extended remote working conditions following the COVID-19 pandemic could have influenced the findings; for example, the challenge that technical expert managers experienced to relate with subordinates may be exaggerated in a remote working environment. Care must be taken before generalising the findings. The study identified potential leadership inefficiencies but did not quantify the impact thereof on the organisation. Research can be done to better understand the impact on and cost to the organisation due to inefficient leadership because of promoting technical experts into managerial positions without adequate support or leadership development.

8.4 The finding that technical expert managers may have limited influence higher up in the hierarchy is thought-provoking. This study focused on subordinates of technical expert managers and technical expert managers. A study that includes the managers of technical expert managers may be insightful.

8.5 The study concluded that a balance between transformational and servant leadership might be best for technical expert managers, but more guidance is needed. There are a few critiques of transformational leadership (Van Knippenberg & Sitkin, 2013; Alvesson & Kärreman, 2016). Further research can be done to better understand the optimal balance and application of different leadership styles by technical expert managers in different circumstances.

8.6 Comprehensive research is required to better prepare and support technical experts for and within leadership positions. The legacy motive for most technical expert managers went beyond just making a difference on a technical level to having an impact on people. Research on how a reflection on legacy motives earlier in a technical expert manager's career may influence leadership behaviour may be interesting.

9. CONCLUSION

9.1 Technical experts as managers offer significant promise to be impactful leaders. Indeed, many emerging technical experts prefer to have a technical expert as a manager, and expert knowledge at the top of organisations offers advantages. However, organisations that want to benefit from improved leadership efficiency must understand the leadership challenges that technical experts as managers may experience and how to assist them to become better leaders. This study aimed to provide insight into these matters.

9.2 Servant leadership that focuses on the growth of subordinates may be helpful to technical experts in overcoming many of the leadership challenges they experience, particularly in the interpersonal domain. However, the study concluded that it might not be ideal for a technical expert manager to solely assume a servant leadership style. Rather the answer to efficient leadership for a technical expert lies in a balance between transformational and servant leadership to achieve an optimal balance in focus between the organisational objectives and the growth and empowerment of subordinates.

ACKNOWLEDGEMENTS

I have grown as a leader through the research and writing process. I am grateful to all the technical experts I previously worked with for the inspiration to conceptualise this research. Thank you to the sixteen participants who found the time in their busy schedules to accommodate the interviews and for their active engagement. Your significant contribution to this research is appreciated.

Many thanks to my husband, who patiently accommodated endless conversations about the research through the ups and downs.

Thank you to my supervisor, Professor Mias de Klerk. His competence in academic research was extremely helpful to me. His valuable and quick feedback, combined with strong support and encouragement, guided me throughout the process of this research assignment.

Finally, thank you to Paul Zondagh for his thoughtful and thorough review of the paper in preparation for the Actuarial Society's Convention.

DISCLAIMER

The views and opinions expressed in this assignment are those of the author and do not reflect the official policy or position of any affiliated agency of the author.

REFERENCES

- Abbas, UI & Daniel, CO (2019). The impact of engaging leadership on organisational performance. *International Journal of Business, Management and Social Research* **6**(2), 367–74. <https://doi.org/10.18801/ijbmsr.060219.39>
- Ackerman, MS, Pipek, V & Wulf, V (2003). *Sharing expertise: Beyond knowledge management*. MIT Press
- Adams, WC (2010). Conducting semi-structured interviews. In: Wholey, JS, Hatry HP & Newcomer, KE (Eds.). *Handbook of practical program evaluation* (3rd ed., pp. 365–76). Jossey-Bass
- Allen, D (2015). *Getting things done. The art of stress-free productivity*. Penguin Books
- Alvarez, K & Van Leeuwen, E (2011). To teach or to tell? Consequences of receiving help from experts and peers. *European Journal of Social Psychology* **41**(3), 397–402. <https://doi.org/10.1002/ejsp.789>
- Alvesson, M & Kärreman, D (2016). Intellectual failure and ideological success in organization studies: The case of transformational leadership. *Journal of Management Inquiry* **25**(2), 139–52. <https://doi.org/10.1177/1056492615589974>
- Bancino, BR & Zevalkink, C (2007). Soft skills: The new curriculum for hard-core technical professionals. *Techniques* **82**(5), 20–23. <https://files.eric.ed.gov/fulltext/EJ764824.pdf>
- Babcock, P (2004). Shedding light on knowledge management. *HR Magazine* **49**(5), 46–50. <https://www.shrm.org/hr-today/news/hr-magazine/pages/0504covstory.aspx>
- Bharwaney, RM (2020). A case study exploring application and development of transformational leadership in chief executive officers of professional services businesses (Order No. 27738380). Available from ProQuest Dissertations & Theses Global. (2359501558). Retrieved from <https://ezproxy.bond.edu.au/login?url=https://www.proquest.com/dissertations-theses/case-study-exploring-application-development/docview/2359501558/se-2>
- Bonaccio, S & Dalal, RS (2006). Advice taking and advice giving in decision making: An integrative review of the literature. *Organizational Behaviour and Human Decision Processes* **101**(2), 127–51. <https://doi.org/10.1016/j.obhdp.2006.07.001>
- Bowie, NE (2000). A Kantian theory of leadership. *Leadership and Organization Development Journal* **21**(4), 185–93. <https://doi-org.ez.sun.ac.za/10.1108/01437730010335427>
- Chatbury, A, Beaty, D & Kriek, HS (2011). Servant leadership, trust, and implications for the ‘base-of-the-pyramid’ segment in South Africa. *South African Journal of Business Management* **42**(4), 57–61. <https://doi.org/10.4102/sajbm.v42i4.505>
- Collinson, S & Wilson, DC (2006). Inertia in Japanese organizations: Knowledge management routines and failure to innovate. *Organization Studies* **27**(9), 1359–87. <https://doi-org.ez.sun.ac.za/10.1177/0170840606067248>
- Cote, R (2017). Vision of effective leadership. *International Journal of Business Administration* **8**(6), 1. <https://doi.org/10.5430/ijba.v8n6p1>
- Cseh, M, Davis, EB & Khilji, SE (2013). Developing a global mindset: Learning of global leaders. *European Journal of Training and Development* **37**(5), 489–99. <https://doi.org/10.1108/03090591311327303>
- Daniel, J (2012). *Sampling essentials: Practical guidelines for making sampling choices*. Sage Publications. <https://dx.doi.org/10.4135/9781452272047.n4>

- Dannhauser, Z & Boshoff, AB (2006). The relationships between servant leadership, trust, team commitment and demographic variables. Paper presented at the Servant Leadership Roundtable at Regent University, Virginia Beach, VA
- Emmel, N (2014). *Sampling and choosing cases in qualitative research: A realist approach*. Sage Publications Ltd. <https://dx.doi.org/10.4135/9781473913882>
- Engward, H, Goldspink, S, Iancu, M, Kersey, T & Wood, A (2022). Togetherness in separation: Practical considerations for doing remote qualitative interviews ethically. *International Journal of Qualitative Methods* **21**(1), 1–9. <https://doi.org/10.1177/16094069211073212>
- Etikan, I & Bala, K (2017). Sampling and sampling methods. *Biometrics & Biostatistics International Journal* **5**(6), <https://doi.org/10.15406/bbij.2017.05.00149>
- Ezzy, D (2010). Qualitative interviewing as an embodied emotional performance. *Qualitative Inquiry* **16**(3), 163–70. <https://doi.org/10.1177/1077800409351970>
- Fast, NJ, Burris, E & Bartel, G (2014). Managing to stay in the dark: Managerial self-efficacy, ego defensiveness, and the aversion to employee voice. *Academy of Management Journal* **57**(4), 1013–34. <https://doi.org/10.5465/amj.2012.0393>
- Ferch, S (2003). *Servant-leadership, forgiveness, and social justice*. The Greenleaf Centre for Servant-Leadership Indianapolis
- Ferris, GR, Liden, RC, Munyon, TP, Summers, JK, Basik, KJ & Buckley, MR (2009). Relationships at work: Toward a multidimensional conceptualization of dyadic work relationships. *Journal of Management* **35**(6), 1379–403. <https://doi.org/10.1177/0149206309344741>
- Fox, M, Tost, L & Wade-Benzoni, K (2015). The legacy motive: A catalyst for sustainable decision making in organisations. *Business Ethics Quarterly* **20**(2), 153–85
- Frankl, VE (2008). *Man's search for meaning*. Rider
- Frick, DM (2004). *Robert K. Greenleaf: A life of servant leadership*. Berrett-Koehler Publishers Inc
- Goodall, AH (2010). *Why we need experts not managers as leaders: The case against professionalizing management education*. Penn State: The Pennsylvania State University. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.475.4808&rep=rep1&type=pdf>
- Gordon, A (2020). How can L and D make subject matter experts more effective? *Training and Development* **47**(4), 15–17. <https://search.informit.org/doi/abs/10.3316/informit.862222130162738>
- Ghosh, AK (2013). Employee empowerment: A strategic tool to obtain sustainable competitive advantage. *International Journal of Management* **30**(3), 95–107. <https://www.proquest.com/docview/1526676689?pq-origsite=gscholar&fromopenview=true>
- Greenleaf, RK (1998). *The power of servant-leadership*. Berrett-Koehler
- Grossman, Z & Owens, D (2012). An unlucky feeling: Overconfidence and noisy feedback. *Journal of Economic Behaviour & Organisation* **84**(2), 510–24. <https://doi.org/10.1016/j.jebo.2012.08.006>
- Gutierrez, LG, Barrales-Molina, V & Tamayo-Torres, J (2015). The knowledge transfer process in Six Sigma subsidiary firms. *Total Quality Management & Business Excellence* **27**(5–6), 613–27. <https://doi.org/10.1080/14783363.2015.1032237>
- Hall, AT, Blass, FR, Ferris, GR & Massengale, R (2004). Leader reputation and accountability in organizations: Implications for dysfunctional leader behavior. *Leadership Quarterly* **15**(4), 515–36. <https://doi.org/10.1016/j.leaqua.2004.05.005>

- Halpin, A & Croft, D (1966). Organizational climate of schools. In: Halpin, A (Ed.), *Theory and research in administration* (pp. 131–249). Prentice Hall
- Hinds, PJ & Pfeffler, J (2003). Why organizations don't 'know what they know': Cognitive and motivational factors affecting the transfer of expertise. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.523.634&rep=rep1&type=pdf>
- Issac, AC, Bednall, TC, Baral, R, Magliocca, P & Dhir, A (2022). The effects of expert power and referent power on knowledge sharing and knowledge hiding. *Journal of Knowledge Management*. <https://doi.org/10.1108/jkm-10-2021-0750>
- Johnson, C (2001). *Meeting the ethical challenges of leadership*. Sage
- Johnston, S & McGregor, H (2005). Recognizing and supporting a scholarship of practice: Soft skills are hard! *Asia-Pacific Journal of Cooperative Education*, 6(1), 1–6. <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.554.3647&rep=rep1&type=pdf>
- Joseph, D, Ang, S, Chang, RHL & Slaughter, SA (2010). Practical intelligence in IT: Assessing soft skills of IT professionals. *Communications of the ACM* **53**(2), 149–54. <https://doi.org/10.1145/1646353.1646391>
- Joseph, EE & Winston, BE (2005). A correlation of servant leadership, leader trust, and organizational trust. *Leadership & Organization Development Journal* **26**(1), 6–22. <https://doi.org/10.1108/01437730510575552>
- Karatepe, OM, Ozturk, A & Kim, TT (2019). Servant leadership, organisational trust, and bank employee outcomes. *Service Industries Journal* **39**(2), 86–108. <https://doi.org/10.1080/02642069.2018.1464559>
- Katou, AA (2015). Transformational leadership and organisational performance: Three serially mediating mechanisms. *Employee Relations* **37**(3), 329–53. <https://doi.org/10.1108/ER-05-2014-0056>
- Kahneman, D (2011). *Thinking fast and slow. Cognition and cognitive psychology*. Farrar, Straus & Giroux
- Kincaid, M (2012). Building corporate social responsibility through servant leadership. *International Journal of Leadership Studies* **7**(2), 151–71. https://www.regent.edu/acad/global/publications/ijls/new/vol7iss2/IJLS_Vol7Iss2_Kincaid_pp151-171.pdf
- King, N & Brooks, J (2018). Thematic analysis in organisational research. In: Cassell, C, Cunliffe, AL & Grandy, G (Eds.). *The SAGE Handbook of Qualitative Business and Management Research Methods: Methods and Challenges* (pp. 219–33). Sage Publications Ltd. <https://dx.doi.org/10.4135/9781526430236.n14>
- King, N & Horrocks, C (2010). *Interviews in Qualitative Research*. Sage
- Kirkman, BL, Chen, G, Farh, JL, Chen, ZX & Lowe, KB (2009). Individual power distance orientation and follower reactions to transformational leaders: a cross-level, cross-cultural examination. *Academy of Management Journal* **52**(4), 744–64. <https://doi.org/10.5465/amj.2009.43669971>
- Klijn, E, De Boer, N & Eshuis, J (2022). Leading frontline enforcers: How supervisors' leadership style impacts inspectors' enforcement style. *Public Management Review* **24**(3), 398–417. <https://doi.org/10.1080/14719037.2020.1833610>

- Kohlberg, L & Kramer, R, (1969). Continuities and discontinuities in child and adult moral development. *Human Development* **12**(2), 93–120. <https://www.jstor.org/stable/26761853>
- Kumar, R & Provodnikova, A (2005). Leadership styles – past, present, and future. https://www.sagepub.com/sites/default/files/upm-binaries/41161_1.pdf
- Larrick, RP (2009). Broaden the decision frame to make effective decisions. In: Locke, EA (Ed.), *Handbook of Principles of Organizational Behavior* (2nd ed, pp. 461–80). Wiley and Sons
- Liden, RC, Wayne, SJ, Zhao, H & Henderson, D (2008). Servant leadership: Development of a multi-dimensional measure and multi-level assessment. *The Leadership Quarterly* **19**(2), 161–77. <https://doi.org/10.1016/j.leaqua.2008.01.006>
- Luthans, F (1988). Successful vs. effective real managers. *Academy of Management Perspectives* **2**(2), 127–32. <https://doi.org/10.5465/ame.1988.4275524>
- Luthans, F & Avalio, B (2003). Authentic leadership development. In: Cameron, KS & Dutton, JE (Eds.), *Positive Organizational Scholarship* (pp. 241–54). Berrett-Koehler
- Magee, JC & Galinsky, AD (2008). 8 Social hierarchy: The self-reinforcing nature of power and status. *The Academy of Management Annals* **2**(1), 351–98. <https://doi.org/10.1080/19416520802211628>
- Mao, J, Chiu, CY, Owens, BP, Brown, JA & Liao, J (2019). Growing followers: Exploring the effects of leader humility on follower self-expansion, self-efficacy, and performance. *Journal of Management Studies* **56**(2), 343–71. <https://doi.org/10.1111/joms.12395>
- Mayer, DM, Bardes, M & Piccolo, RF (2008). Do servant-leaders help satisfy follower needs? An organizational justice perspective. *European Journal of Work and Organizational Psychology* **17**(2), 180–97. <https://doi-org.ez.sun.ac.za/10.1080/13594320701743558>
- Moser, KS (2017). The influence of feedback and expert status in knowledge sharing dilemmas. *Applied Psychology* **66**(4), 674–709. <https://doi.org/10.1111/apps.12105>
- Muli, BM (2022). Credible and authentic leadership development in organisations. *Science Journal of Business Management* **10**(1), 36–46. <https://doi.org/10.11648/j.sjbm.20221001.16>
- Nahavandi, A (2015). *The art and science of leadership* (7th ed.). Pearson
- Nasor, M (2019). *Leader credibility in corruption eradication*. <https://doi.org/10.4108/eai.10-9-2019.2289329>
- Olsen, W (2012). *Data collection: Key debates and methods in social research*. Sage Publications Ltd. <https://dx.doi.org/10.4135/9781473914230.n6>
- Panagiotopoulos, A (2010). *From technical expert to project manager: Punishment or salvation?* <http://oceanis.lib.teipir.gr/xmlui/handle/123456789/586>
- Park, N & Peterson, G (2003). Virtues and organizations. In: Cameron, KS, Dutton, JE & Quinn, RE (Eds.). *Positive organizational scholarship: Foundations of a new discipline* (pp. 33–47). Berrett Koehler
- Parolini, JL (2007). Investigating the distinctions between transformational and servant leadership [Doctoral dissertation, Regent University, Virginia Beach, VA]
- Parris, DL & Peachy, JW (2013). A systematic literature review of servant leadership theory in organisational context. *Journal of Business Ethics* **113**(3), 377–93. <https://www.jstor.org/stable/23433856>

- Patterson, K (2003). *Servant leadership: A theoretical model* [Doctoral dissertation, Graduate School of Business, Regent University]. <https://www.proquest.com/docview/305234239?pq-origsite=gscholar&fromopenview=true>
- Peter, LJ & Hull, R (1969). *The Peter Principle*. Buccaneer Books
- Phillips-Wren, G, Power, DJ & Mora, M (2019). Cognitive bias, decision styles, and risk attitudes in decision making and DSS. *Journal of Decision Systems* **28**(2), 63–6. <https://doi.org/10.1080/12460125.2019.1646509>
- Quinn, RE (1996). *Deep change. Discovering the leader within*. Jossey-Bass
- Rego, A, Cunha, MP e & Simpson, AV (2018). The perceived impact of leaders' humility on team effectiveness: an empirical study. *Journal of Business Ethics* **148**(1), 205–18. <https://doi.org/10.1007/s10551-015-3008-3>
- Reinke, SJ (2003). Does the form really matter? Leadership, trust, and acceptance of the performance appraisal process. *Review of Public Personnel Administration* **23**(1), 23–37. <https://doi-org.ez.sun.ac.za/10.1177%2F0734371X02250109>
- Reinke, SJ (2004). Service before self: Towards a theory of servant-leadership. *Global Virtue Ethics Review* **3**(5), 30–57. <http://dx.doi.org/10.1016/j.jaci.2012.05.050>
- Rockenbach, B & Milinski, M (2006). The efficient interaction of indirect reciprocity and costly punishment. *Nature* **444**(7120), 718–23. <https://doi.org/10.1038/nature05229>
- Saltman, RB & Ferroussier-Davis, O (2000). The concept of stewardship in health policy. *Bulletin of the World Health Organization* **78**(6), 732–39
- Sheather, J & Slattery, D (2021). The great resignation – how do we support and retain staff already stretched to their limit? *BMJ* **2021**, **375**(2533). <https://doi.org/10.1136/bmj.n2533>
- Smith, BN, Montagno, RV & Kuzmenko, TN (2004). Transformational and servant leadership: Content and contextual comparisons. *Journal of Leadership & Organizational Studies* **10**(4), 80–91. <https://doi.org/10.1177/107179190401000406>
- Sousa, M, Cunha, MPE, Ace, V, Simpson, LG, Rego, A & Clegg, S (2022). *Servus or Pater? How paradoxical intent can qualify leadership: Inductions from the Kingdom of Bhutan*. *Journal of Change Management: Reframing leadership and organisational practice* **22**(3), 321–53. <https://doi.org/10.1080/14697017.2022.2032271>
- Sousa, M & Van Dierendonck, D (2017). Servant leadership and the effect of the interaction between humility, action, and hierarchical power on follower engagement. *Journal of Business Ethics* **141**(1), 13–25. <https://doi.org/10.1007/s10551-015-2725-y>
- Spreier, SW, Fontaine, MH & Malloy, RL (2017). The destructive potential of overachievers. *Harvard Business Review*, June 2006. <https://hbr.org/2006/06/leadership-run-amok-the-destructive-potential-of-overachievers>
- Stone, A, Russell, RF & Patterson, K (2004). Transformational versus servant leadership: A difference in leader focus. *Leadership & Organization Development Journal* **25**(4), 349–61. <https://doi.org/10.1108/01437730410538671>
- Tangney, JP (2009). Humility. In Lopez, S & Snyder, C (Eds.), *Oxford Handbook of Positive Psychology* (pp. 483–90). Oxford University Press

- Taylor, E & Benbow, RJ (2016). Investigating the perception of stakeholders on soft skills development of students: Evidence from South Africa. *Interdisciplinary Journal of e-Skills and Lifelong Learning* 12, 1–18. <http://www.ijello.org/Volume12/IJELLv12p001-018Taylor2494.pdf>
- Tost, LP, Gino F & Larrick, RP (2012). Power, competitiveness, and advice taking: Why the powerful don't listen. *Organizational Behavior and Human Decision Processes* 117(1), 53–65. <https://doi.org/10.1016/j.obhdp.2011.10.001>
- Van Dierendonck, D (2011). Servant leadership: A review and synthesis. *Journal of Management* 37(4), 1228–61. <https://doi.org/10.1177/0149206310380462>
- Van Knippenberg, D & Sitkin, SB (2013). A critical assessment of charismatic-transformational leadership research: Back to the drawing board? *Academy of Management Annals* 7(1), 1–60. <https://doi.org/10.5465/19416520.2013.759433>
- Wadhwa, A & Mahant, S (2022). Humility in medical practice: A qualitative study of peer-nominated clinicians. *BMC Medical Education* 22(1), 1–9. <https://doi.org/10.1186/s12909-022-03146-8>
- Wang, Z, Yu, K, Xi, R & Zhang, X (2019). Servant leadership and career success: The effects of career skills and proactive personality. *Career Development International* 24(7), 717–30. <https://doi.org/10.1108/CDI-03-2019-0088>
- Whisnant, B & Khasawneh, O (2014). The influence of leadership and trust on the sharing of tacit knowledge: Exploring a path model. *Journal of Business Studies Quarterly* 6(2), 1–17. <https://www.proquest.com/docview/1640729843?pq-origsite=gscholar&fromopenview=true>
- Wiseman, L (2017). *Multipliers*. Harper Business, an imprint of HarperCollins Publishers
- Yukl, G (2012). Effective leadership behavior: What we know and what questions need more attention. *Academy of Management Perspectives*, 26(4), 66–85. <https://doi.org/10.5465/amp.2012.0088>

Towards the development of a three-state Markov Chain model of working life expectancy in South Africa

By GA Whittaker, K Naidoo and M Lawrence

Submission date 29 September 2022

Acceptance date 1 November 2023

ABSTRACT

Courts are able to exercise broad discretion when they assess the quantum of damages due to loss of earning capacity and have considerable discretion in making an award. South African courts have adopted the approach that an actuarial computation is a valuable basis for establishing the quantum of damages. Actuarial calculations, by their nature, account for certain contingency factors such as inflation, income tax, mortality and the retirement age. It is commonplace to deduct a general contingency where the actuarial calculation makes no explicit allowance. General contingencies cover many considerations that vary from case to case. The only real difference between mortality and other contingencies is that more evidence is available in statistical form to show mortality rates. Despite various data limitations that do not currently allow for a full implementation of the model, this paper seeks to develop a three state Markov Chain model of working life expectancy in South Africa by gender and broad education level. Working life expectancy is inextricably linked to general contingency deductions and the results of this paper challenge some common law conventions and the level of general contingency deductions that have been adopted by South African courts.

KEYWORDS

Working life expectancy, Markov Chain model, actuarial evidence, common law, general contingency deductions, labour force statistics

CONTACT DETAILS

Gregory Whittaker, University of the Witwatersrand, Algorithm Consultants & Actuaries, 222 Rivonia Road, Morningside, Sandton, 2196; Tel: +27 (0)11 802 0263; Email: gregory@algorithm-ca.com

1. INTRODUCTION

1.1 Background

1.1.1 The basic principle underlying an award of damages for bodily or fatal injury is that compensation must be assessed so as to place the plaintiff, as far as possible, in the same position had the unlawful act or delict not been committed (Corbett et al., 1995). Damages recoverable in delict are either classified as special damages or general damages (Visser & Potgieter, 2004).

1.1.2 Special damages include all monetary loss actually incurred up to the date of trial such as past medical expenses and past loss of income. General damages include non-monetary loss such as pain and suffering, loss of amenities of life and disfigurement. General damages also include monetary loss which, up to the date of trial, have not yet materialised, such as future medical expenses and future loss of income (Corbett et al., 1995).

1.1.3 Du Plessis (2012) notes that South African courts readily consult and rely on actuarial opinion when determining monetary compensation, and concludes that such reliance is rational. Where the actuarial approach is adopted in future loss of income claims, a four-stage procedure can be derived from Koch (1984):

1.1.3.1 STEP (I): Ascertain the likely career path of the plaintiff had the accident or incident that caused the loss not occurred. In so doing, assessments are conducted to ascertain the plaintiff's academic qualifications, vocational qualifications, career history, historic job roles, available job roles and the chances of promotion, historic earnings and the remuneration package including fringe benefits at the date of the accident, working life expectancy and likely retirement age.

1.1.3.2 STEP (II): The actuary is provided with the raw data set out in Step (i) and then proceeds to calculate the present value of future income had the accident or incident not occurred. The actuary is required to make assumptions concerning the after-tax rate of interest that would be earned on the investment of the award, future rates of consumer price inflation, an allowance for general productivity increases, an allowance for mortality by selecting an appropriate mortality table and an assumption concerning future tax rates.

1.1.3.3 STEP (III): Step (i) and Step (ii) above are repeated for the situation now that the accident or incident has occurred.

1.1.3.4 STEP (IV): On completion of the above steps, a final adjustment is made for general contingency deductions (other than life contingencies). Such adjustment is made in respect of both income streams. Once a deduction for general contingencies is made, the plaintiff's net loss of income can be determined by subtracting the value of income now that the incident has occurred from the value of income had the accident not occurred. This is referred to as the differencing rule (Du Plessis, 2012).

1.1.4 The above four-stage procedure is followed whenever compensation by way of a lump sum is to be calculated. It has been, and still is, possible, however, for the parties to a claim in terms of the Road Accident Fund Act to agree to compensation for loss of income by way of instalments.¹

1 Section 17(4)(b) of the *Road Accident Fund Act* 56 of 1996

1.1.5 This paper concerns itself with an element of Step (i) of the above procedure which is the determination of working life expectancy. Working life expectancy (WLE) can be defined as the expected number of years an individual will be in paid employment, or the expected number of years an individual will be economically active. With respect to the latter definition, WLE calculations consider time spent in employment and unemployment. This paper concerns itself with the former definition. To date no expert evidence has been presented in South African courts concerning WLE. The WLE is in turn inextricably linked to Step (iv) of the above procedure which is the determination of the level of general contingency deductions that may be applied in a claim for future loss of income. To date the courts have applied various approaches in determining contingency deductions as discussed in Section 2.

1.2 Importance of this research

1.2.1 There has been no contribution from the actuarial community concerning an empirical basis for determining WLE and in turn general contingency deductions in South Africa. In the landmark case of *Southern Insurance Association v Bailey*,² the court favoured an actuarial computation in the determination of damages on the basis that it represented an attempt to ascertain the loss of income on a logical basis. Despite common law conventions, aspects of general contingency deductions lend themselves to actuarial computation. A review of this principle means developing the common law as envisaged by the Constitution. Aside from applications in the assessment of damages setting, WLE tables are essential for the analysis of work force progression, retirement trends and educational planning (Hoem, 1977). WLE tables can also be used to measure the success of labour market policy.

1.2.2 The common law convention of referring to prior case law in deciding general contingency deductions, coupled with the court's general impressions of a case, must be tested against available empirical evidence.

1.3 Aims

1.3.1 The aim of this paper is to develop tables of WLE by gender and broad levels of education using available panel data. In turn, these estimates can be used to test the level of general contingency deductions applied by the courts.

1.3.2 Whilst fulfilling this aim, the paper also seeks to fulfil the following aims:

- Describe the principles underlying general contingency deductions in the legal context.
- Investigate the methodology involved in constructing WLE tables.
- Construct a WLE table for South Africa from available panel data.
- Determine the general contingency deductions that can be derived from the WLE tables.

1.4 Plan of development

1.4.1 The paper unfolds as follows: Section 2 provides an overview of relevant case law and Section 3 provides a literature review. Section 4 provides an overview of the data and Section 5 describes the methodology used to construct the WLE tables. Section 6

2 *Southern Insurance Association Ltd v Bailey* 1984 1 SA 98 (A)

discusses the results of the analysis and Section 7 discusses the limitations of the model. The paper concludes in Section 8.

2. RELEVANT CASE LAW

*A court is not a casino.*³

2.1 Boberg (1964) notes that the term “general contingencies” traditionally denotes all the uncertainties, hazards and vicissitudes of life, and its introduction into the assessment of damages is based on the fact that the courts are required to speculate on the future as it would have been but for the accident and now having regard to the accident. In *Hulley v Cox*,⁴ the court noted that:

It is at any rate desirable to test the result of an actuarial calculation by a consideration of the general equities of the case.

2.2 Many cases involving actuarial evidence require determining the actuarial value of income from employment. As noted in *Road Accident Fund v GSO Guedes*,⁵ the court exercises a broad discretion when it assesses the quantum of damages due to loss of earning capacity and has a considerable discretion to award what it considers appropriate. South African courts have adopted the approach that in order to assist in such a calculation, an actuarial computation is a valuable basis for establishing the quantum of damages.

2.3 The authoritative case with respect to actuarial calculations is *Southern Insurance Association Ltd v Bailey*⁶ in which it was held that:

All that the Court can do is to make an estimate, which is often a very rough estimate, of the present value of the loss. It has open to it two possible approaches. One is for the Judge to make a round estimate of an amount which seems to him to be fair and reasonable. That is entirely a matter of guesswork, a blind plunge into the unknown. The other is to try to make an assessment, by way of mathematical calculations, on the basis of assumptions resting on the evidence. The validity of this approach depends of course upon the soundness of the assumptions, and these may vary from the strongly probable to the speculative. It is manifest that either approach involves guesswork to a greater or lesser extent. But the Court cannot for this reason adopt a non possumus attitude and make no award. ... In a case where the Court has before it material on which an actuarial calculation can usefully be made, I do not think that the first approach offers any advantage over the second. On the contrary, while the result of an actuarial computation may be no more than an ‘informed guess’ it has the advantage of an attempt to ascertain the value of what was lost on a logical basis; whereas the trial Judge’s ‘gut feeling’ (to use the words of appellant’s counsel) as to what is fair and reasonable is nothing more than a blind guess.

3 Judge Willis in *NK obo ZK v Member of the Executive Council for Health of the Gauteng Provincial Government* (216/2017) [2018] ZASCA 13; 2018 (4) SA 454 (SCA)

4 *Hulley v Cox* [1923] AD

5 *Road Accident Fund v GSO Guedes* [2006] SCA 18

6 *Southern Insurance Association Ltd v Bailey* 1984 1 SA 98 (A)

2.4 In *Dlamini v Road Accident Fund*⁷ it was noted that the court's historic wide discretion in assessing awards for past and future loss of earnings has been attenuated by the practice of obtaining actuarial input.

2.5 However, where a court assesses that there is uncertainty regarding a plaintiff's pre-accident employment history and the evidence on which to base calculations is not credible, actuarial calculations may be rejected in favour of a globular award, such as in *January v The Minister of Police*.⁸

2.6 In *Smit v Road Accident Fund*,⁹ it was noted that actuarial calculations by their nature take into account certain contingency factors such as inflation, income tax, mortality and the retirement age. It is commonplace for a deduction to be made for general contingencies for which no explicit allowance has been made in the actuarial calculation.

2.7 As noted in *RAF v CK*,¹⁰ general contingencies cover many considerations that vary from case to case. These include the possibility of errors in the estimation of future life expectancy and retirement age; the likelihood of illness and unemployment which would have occurred in any event; savings in relation to work travel; other contingencies which would have affected earning capacity in any event; loss of pension benefits from frequent changing of employment; economic adversity; and other unforeseen events.

2.8 Despite actuaries being well versed in statistics concerning, for example, morbidity risks, a rigorous application of these types of statistics to compensation cases has met resistance. For example, in *Shield Insurance Co Ltd v Hall*,¹¹ the court expressed the view that the actuary giving evidence in the matter was in no position and not qualified to give evidence as to the hazards and contingencies applicable to any particular type of work.

2.9 Further, in *Oosthuizen v Road Accident Fund*:¹²

But the Court emphasised that provision for contingencies falls squarely within the subjective discretion of the court as to what is reasonable and fair. This will depend upon the underlying assumptions made which are not the domain of the actuary.

2.10 As correctly noted in *RAF v Sweatman*,¹³ the only real difference between mortality and other contingencies is that more evidence is available in statistical form to show mortality rates.

7 *Dlamini v The Road Accident Fund* (21375/2019) [2022] ZAGPJHC 657

8 *January v Minister of Police* [2022] ZANCHC 51

9 *Smit v Road Accident Fund* (1820/10) [2013] ZAECGHC 57

10 *RAF v C K* (1024/2017) [2018] ZASCA 151

11 *Shield Insurance Co Ltd v Hall* 1976 (4) SA 431 (A)

12 *Oosthuizen v Road Accident Fund* (2014/04972) [2015] ZAGPJHC 172

13 *RAF v Sweatman* (162/2014) [2015] ZASCA 22

2.11 In *Goodall v President Insurance*,¹⁴ it was held that:

When assessing damages for future loss of earnings, in an action for damages for personal injuries sustained, in the assessment of a proper allowance for contingencies arbitrary considerations must inevitably play a part, for the art or science of foretelling the future, so confidently practised by ancient prophets and soothsayers, and by modern authors of a certain type of almanack, is not numbered among the qualifications for judicial office.

2.12 Despite no empirical evidence, in some matters such as *Oosthuizen v Road Accident Fund*,¹⁵ *Pierre v Road Accident Fund*,¹⁶ and *Coetsee v Road Accident Fund*,¹⁷ the courts have adopted the so-called sliding scale approach. Under that approach the contingency deduction is determined on the basis of ½% for each year from the calculation date to the age of retirement. For example, a 35-year-old that would have retired at age 65 would attract a general contingency deduction of 15% (30 years until retirement multiplied by ½% a year). In *Dlamini v Road Accident Fund*,¹⁸ the court stated that:

The authorities indicate that a sliding scale approach of 0.5% per annum for every year over the period that income must be determined should be applied, to achieve the best estimate of the plaintiff's damages.

2.13 Koch (1984) notes that recognition has been given to the principle that a short period of exposure to the risk of adversity justifies a lower deduction than a longer period, or the so-called widening funnel of doubt principle as set out in *Haigh v Road Accident Fund*.¹⁹

2.14 In *NK obo ZK v MEC for Health, Gauteng*²⁰ it was noted that whilst conjecture may be required in making a contingency deduction, it should not be done whimsically. In particular the approach of splitting a contingency deduction down the middle (in other words, simply taking the average between what respective parties contend should be the contingency deduction), without explanation, is devoid of any rational connection between the means by which the decision was made and the result of the decision-making process.

2.15 In *Mokone v Road Accident Fund*,²¹ determination of contingency deductions involves: ... the manner in which the plaintiff, given her particular circumstances, would fare as compared the established norm ... These are applied by the court dealing with the case in order to adjust the loss to reflect as closely as possible the real circumstances of the plaintiff. This is a delicate exercise which is an important judicial function.

14 *Goodall v President Insurance* 1978 1 SA 389 (W)

15 *Ibid* 12

16 *Pierre v Road Accident Fund* (44981/2013) [2015] ZAGPJHC 159

17 *Coetsee v Road Accident Fund* (2871/2018) [2021] ZAFSHC 193

18 *Ibid* 7

19 *Haigh v Road Accident Fund* (25947/2016) [2019] ZAGPPHC 945

20 *Ibid* 3

21 *Mokone v Road Accident Fund* (22403/2015) [2022] ZAGPPHC 702

2.16 With the exception of *Nienaber v Road Accident Fund*²² and *Njoko v Minister of Safety and Security and Another*,²³ the concept of WLE has rarely been mentioned by South African courts. The literature on WLE is well developed internationally as discussed in Section 3. Knowledge of WLE would provide the court with a further tool in establishing norms and assisting with the important judicial function of setting contingency deductions.

3. LITERATURE REVIEW

3.1 Conventional model

3.1.1 First proposed by Wolfbein (1949), the conventional WLE model is computed as the joint probability of age-specific rates of survival from population mortality tables and assumed stationary labour force participation rates by age. The joint probability of survival from time to time coupled with the labour force participation rate for each age is summed from each age x until the assumed terminal age so as to obtain the conventional WLE estimate. The classical working life table is static in nature because it is based on data from a single point in time, such as census data.

3.1.2 The conventional WLE model, as with all life table methodology, is based on the concept of a stationary population (Smith, 1982). Stationarity of the labour market means that there is only one transition into and out of the labour force (Verrall et al., 2005). The conventional WLE model is also characterised by the assumption of unimodality. That is, there is a single peak in the distribution of the mobility of the population which is a consequence of the stationarity assumption. Bloomfield & Haberman (1990) note that unimodality is observed in the graph of participation rates against the age of individuals in the labour force, where a single peak is evident around the ages of 16 to the early 20s which is when most individuals enter the labour market.

3.1.3 A number of limitations are inherent in the conventional WLE model. Given the assumption of stationarity, the model does not consider the numerous entries and exits from the labour force of an individual, which is not realistic. The conventional WLE model does not account for an individual's current labour force status which would control his/her labour force participation in the future (Skoog & Ciecka, 2001). Hence, an individual presently in the labour force and an individual of the same age and gender outside of the labour force, will be treated in the same manner.

3.1.4 Whilst unimodality may be considered normal for male participation rates, bimodality is seen to be more accurate for female participation rates, where bimodality refers to the distribution of mobility of females in and out of the workforce exhibiting two peaks (Krueger, 2004). Based on Smith (1982), females present bimodal patterns as their entries and exits out of the workforce may be a result of changes in their parental or marital status. Bloomfield & Haberman (1990) state that even if bimodality was incorporated into the classical approach, for example, by splitting the population by marital status, the comparison

22 *Nienaber v Road Accident Fund* (A5012/11) [2011] ZAGPJHC 150

23 *Njoko v Minister of Safety and Security and Another* (2011 (5) SA 512 (KZP)) [2011] ZAKZPHC 25; 1565/09

of results for the two genders would be made difficult due to the application of different techniques for each gender. However, these alterations to incorporate bimodality would still require the assumption of stationarity (Bloomfield & Haberman, 1990).

3.1.5 Information on workforce participation is collected at one point in time, such as from a census. It would be more appropriate to identify the dynamic nature of workforce participation and use labour force survey data that relates to the entries and exits from the workforce. Hence, the classical approach suffers a major structural flaw as the workforce participation rates on which it is based are static in nature. It would be better to use cohort-based data instead of the cross-sectional data which is utilised by this approach (Bloomfield & Haberman, 1990).

3.1.6 The conventional WLE model is artificial, in the sense that the WLE table provides a summary of workforce participation behaviour for all ages in the population over a specified period and does not track the individuals through their lifetimes. Hence, it provides a synthetic overview of the inherent decrements which may give deceptive ideas of the trends in the inherent workforce participation rates and become outdated over time (Bloomfield & Haberman, 1990).

3.2 Markov Chain model

3.2.1 The Markov Chain model is built on the foundation of the multi-state life table, also known as the increment-decrement approach (Krueger, 2004). The earliest published study of the multi-state life table is due to du Pasquier (1913), and the model allows for movement back and forth between at least two states, as well as movement into an absorbing state, commonly known as the death state (Krueger, 2004).

3.2.2 Built on the foundation of the multi-state life table, the earliest published WLE tables using that method are accredited to Hoem & Fong (1976). The WLE tables were derived from panel labour force surveys of the Danish male population from 1972–1974. A Markov Chain model was undertaken in this study, resulting in more credible and realistic results based on the data capture of labour force mobility. The WLE table modelled the transition probabilities for labour force participation based on active participation, inactive participation and exit to death, by age. Hoem & Fong (1976) defined an individual as ‘active’ if he/she is either employed or actively seeking employment, whereas an individual is defined to be ‘inactive’ if he/she is not employed and not actively seeking employment. The raw transition probabilities were smoothed using a moving average.

3.2.3 The Markov Chain framework models the labour force as a dynamic process (Smith, 1982). It considers the transition of individuals into and out of the workforce over an individual’s working lifetime as well as his/her initial labour force status (Bloomfield & Haberman, 1990). It permits the calculation of the time spent in various activity states (Verrall et al., 2005). The Markov Chain model is an improvement on the classical approach, as it is based on data that considers the labour flows of the workforce and it is not from a single point in time (Hoem & Fong, 1976).

3.2.4 The first use of the Markov Chain model for constructing WLE tables in the United States was that by Schoen & Woodrow (1980). That study used Current

Population Survey (CPS) data from 1972 and 1973 for labour force activity and the 1972 US Life Tables for mortality data. The CPS dataset was ideal for the purpose of capturing the dynamics of the labour force, because it was designed as an aggregate rotating survey of the population, meaning that it overcame the difficulty of maintaining a high response rate, which arises from permanent sample surveys, and overcame the limitation of using a new sample each period, which can result in a higher variance in estimates of change (Krueger, 2004). Although the sizes of the samples were not recorded, it was noted that transition probabilities were smoothed using a 9th-order centred moving average for males and a 7th-order centred moving average for females. The study did not report the WLE for individuals whose initial state was inactive in the labour force (Krueger, 2004).

3.2.5 The Markov Chain model became the paradigm utilised when calculating WLE after its publication in the Bureau of Labour Statistics Bulletin by Smith (1982) and Smith (1986), which publicised the change from the conventional models (Skoog et al., 2011). The 1986 WLE tables by Smith are credited as the first time that WLE tables were extended to include WLE by race and education for each gender but not race and education simultaneously (Millimet et al., 2003). In both years, Smith used the 1970 and 1971 CPS labour force data, and the US life tables for mortality data (Smith, 1986). The method of smoothing the transitional probabilities was not reported in the 1982 research, however in the 1986 tables, it was reported that transition probabilities were smoothed using a 9th-order centred moving average (Krueger, 2004).

3.2.6 Further attempts to improve the WLE tables for the US population were undertaken by Ciecka et al. (1995), Skoog & Ciecka (2001) and Abele & Richards (1999), however, the differences in comparable results were found to be minimal (Krueger, 2004).

3.2.7 Millimet et al. (2003) attempted to improve the WLE tables published by Smith (1986) using the same methodology with the exception of adopting a logit model to estimate transitional probabilities instead of the more traditionally used relative frequency method (Krueger, 2004). This study was based on nine years of CPS data from 1992 to 2000, which meant that the results were not as sensitive to economic conditions as the results of Smith (1986) which were based on one year of data. Whilst previous WLE models were based on only the employed and unemployed state, this model was enhanced by categorising individuals into three states, namely the employed, unemployed and inactive. The transition between states was modelled as a function of age, race, sex, marital status, number of children, and occupation. Although Millimet et al. (2003) concluded that their WLE tables produced significantly more precise estimates, Krueger (2004) remarks that the differences in the results when compared to Smith (1986) were negligible.

3.2.8 In 2004, Krueger extended the Markov Chain model of constructing WLE tables to incorporate age-based economic characteristics such as earning capacity. These tables were based on the US population and used 1998 to 2004 CPS data and US life tables for labour force activity and mortality rates, respectively. These were the first WLE tables that presented labour force participation probability projections that could be connected to age-specific earning capacity forecasts.

3.2.9 As described above, extensive research on and publication of WLE tables

have been carried out in the United States following the work done by Smith in 1982 and 1986. As noted in Watt et al. (2019), the Australian Actuary Department has only produced life expectancy tables in the past, and there is no published WLE table for the Australian population by the department. However, the Australian Bureau of Statistics (ABS) and the Household, Income and Labour Dynamics in Australia (HILDA) acts as an alternative source of data regarding calculations pertinent to WLE. Although it was not the purpose of the Watt et al. (2019) paper to construct WLE tables for the Australian population, they stated that the data could be sourced for the population and a Markov Chain model was viable.

3.2.10 In Asia, the Markov Chain model has been applied to Vietnamese data in research performed by Samaniego & Viegelahn (2021). The research was based on workforce participation data collected in the Vietnamese labour force surveys for 2011 to 2019. These surveys are also performed in a rotating panel manner, where individuals can be tracked across different quarters in a year, but not across years (ILO, 2021). This study was similarly based on the increment-decrement approach and considered transitions between three states, namely employed, unemployed and inactive; transitions between the formality of the job, the economic sector and the different occupation types were looked at as well (ILO, 2021).

3.2.11 In the United Kingdom (UK), the Government Actuary's Department (2022) publishes actuarial tables for use in personal injury and fatal accident cases. Included in the so-called Ogden tables are tables of contingencies other than mortality. The reduction factors adjust the baseline multiplier in the Ogden tables to reflect the average pre-injury and post-injury contingencies according to the employment risks associated with the age, sex, employment status, disability status and educational attainment of the claimant when calculating awards for loss of earnings. The method of calculation, based as it is on three broadly defined characteristics, will not capture all the factors which might be expected to affect the claimant's future earnings.

3.2.12 As noted by Hoem & Fong (1976), the Markov Chain model requires fewer assumptions. As noted in Verrall et al. (2005), this model makes use of one process for both genders and all ages, thus the consequential variation in group rates may be ascribed to actual variation in the behaviour of the workforce, instead of bias created by the model. Hence, the Markov Chain model does not suffer from the issues surrounding the use of a bimodal curve of workforce participation rates (Verrall et al., 2005).

3.2.13 The main limitation of the model is that it requires more data, as it uses longitudinal data which is meant to improve the quality of results. As a result, the Markov Chain model requires greater standards of data processing procedures (Bloomfield & Haberman, 1990). Additionally, the complex nature of the required datasets might lead to reliability issues within the datasets as there is a greater chance for misreporting of workforce status, especially regarding temporary and part-time employees, as described by Hoem (1977).

4. DATA SOURCES

4.1 General comments

4.1.1 The Markov Chain model of WLE requires three fundamental data inputs that in turn require derivation from a variety of sources. This is because the three fundamental inputs are not covered by one survey in South Africa.

4.1.2 The first input into the model is in respect of the labour force. In particular, for those alive at each age x , an estimate is required of the number of persons who are either active or inactive in the labour force. To this end the Quarterly Labour Force Survey (QLFS) covering the second quarter of 2022 was used. That survey contained a sample of 57,244 individuals. Sample weights are used to estimate the number of individuals in the active state at every age (^aN_x) and the number of individuals in the inactive state at every age (^iN_x), giving a total population size at each age of N_x . The numbers of individuals in the active and inactive states were determined across gender and broad educational level. Persons with no schooling, Grade R to Grade 11, an N1 or N2, and those who did not know their schooling level were coded as having less than a Grade 12. The balance of the population was coded as having a Grade 12 or higher level of education.

4.1.3 The second input required for the model is an estimate of transition rates between states. In particular, for those alive at age x and at age $x+1$ who are active in the labour force at age x , what proportion of those persons are still active in the labour force at age $x+1$? Similarly, for those alive at age x and age $x+1$ who are inactive in the labour force at age x , what proportion of those persons are still inactive in the labour force at age $x+1$? Discussion surrounding suitable data for estimating transition probabilities is set out in Section 4.2 and Section 4.3.

4.1.4 Lastly, an appropriate mortality table is required in order to estimate the proportion of persons who are still alive at age $x+1$ out of living persons at age x . A discussion regarding a suitable mortality table is set out in Section 4.4.

4.2 Labour market dynamics in South Africa

4.2.1 Statistics South Africa (StatsSA) produces an annual Labour Market Dynamics in South Africa publication (LMD) that contains an amalgamation of data from the QLFS for each quarter in the calendar year, but only covers the labour market activities of persons aged 15–64 years.

4.2.2 The QLFS makes it possible to track individuals from one quarter to the next and hence panel data can be constructed so as to analyse transition rates between various states in the labour market. In each edition of the LMD, panel data summaries are provided that measure quarterly rates of transition between various starting states, such as the transition of employed individuals to employed individuals. The results reported in the LDS panel are after the application of sample weights.

4.2.3 The quarterly rates of transition for Quarter 3 to Quarter 4 from employed to employed, and for not employed to employed, is shown in Figure 1. It can be observed that transition rates have remained fairly stable from 2012 to 2020 when examining flows from Quarter 3 to Quarter 4 of each year:

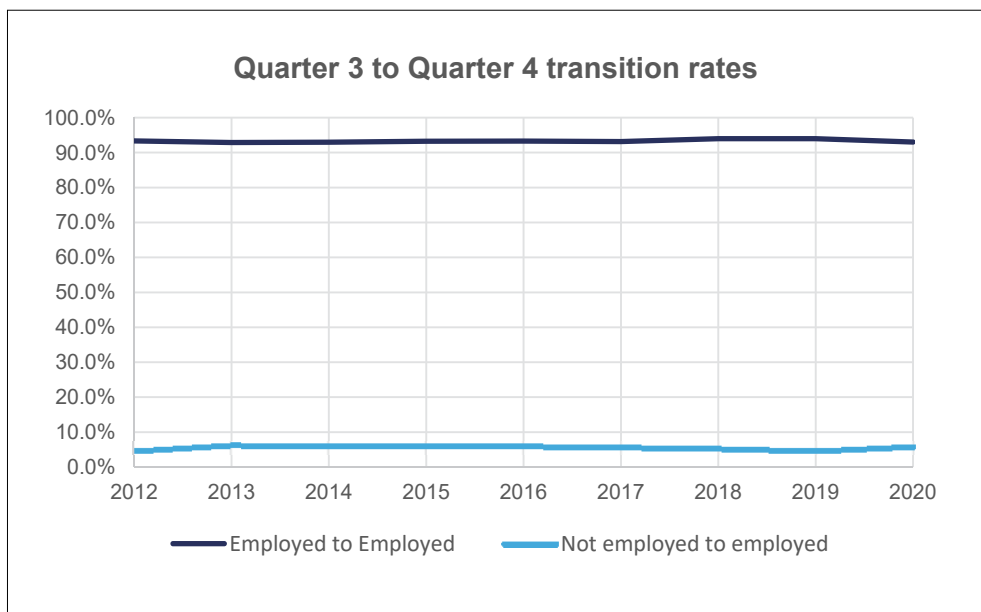


FIGURE 1. Quarterly transitions from 2012–2020

4.2.4 The only time that quarterly transition rates from employed to employed were less than 90% was for Quarter 1 of 2020 to Quarter 2 of 2020. This coincides with the COVID-19 pandemic and the government announcement of a national lockdown commencing on 27 March 2020. On 21 April 2020, a R500 billion stimulus package was announced in response to the pandemic, with the lockdown level reducing to Level 4 from 1 May 2020 and Level 3 from 1 June 2020.

4.2.5 StatsSA have only once released panel data which were for Quarter 3 of 2013 to Quarter 4 of 2013. That survey contained a sample of 35,744 individuals between the age of 15 and 64. The quality of the QLFS panel is tested by StatsSA and a report on quality diagnostics for the panel data is produced.

4.2.6 Data were recoded to reflect those who are active (employed) and those who are inactive (unemployed or not economically active). The same process as noted in 4.1.2 above was used to split the sample between those with less than a Grade 12 and those with a Grade 12 or higher level of education. Eight separate groups were determined based on a combination of gender, active or inactive status at the beginning of the quarter, and broad education level. The education level was assumed to remain constant over the quarter based on the education level at the beginning of the quarter. Raw rates of transition were determined by age for each group after applying sample weights.

4.2.7 The definition of those employed was not altered from the definition used by StatsSA. In particular, employed persons were considered to be those persons between the ages of 15 and 64 who, during the reference week, did any work for at least one hour, or had a job or business but were temporarily absent. Definitions of unemployment and not

economically active were not considered, as an individual was simply classified as employed (active) or not employed (inactive).

4.2.8 The panel dataset reflected the whole age of each survey participant. Once raw quarterly transition rates were determined, these were projected for a whole year such that an estimate of transition rates for each age was obtained as follows:

$$P_{x:x+1/4} = \begin{bmatrix} p_{11,x:x+1/4} & p_{12,x:x+1/4} \\ p_{21,x:x+1/4} & p_{22,x:x+1/4} \end{bmatrix} \quad (1)$$

$$P_{x:x+1} = P_{x:x+1/4}^4 \quad (2)$$

where:

$P_{x:x+1/4}$ = the transition matrix from age x to age $x + 1/4$.

$p_{11,x+1/4}$ = the probability that an individual aged x who was employed at age x , remains employed at age $x + 1/4$.

$p_{12,x+1/4}$ = the probability that an individual aged x who was employed at age x , is not employed at age $x + 1/4$.

$p_{21,x+1/4}$ = the probability that an individual aged x who was not employed at age x , becomes employed at age $x + 1/4$.

$p_{22,x+1/4}$ = the probability that an individual aged x who was not employed at age x , remains not employed at age $x + 1/4$.

$P_{x:x+1}$ = the estimated transition matrix from age x to age $x + 1$.

4.2.9 On request, StatsSA provided a further panel data file that has not been previously released, covering the period from Quarter 3 of 2019 to Quarter 4 of 2019 (just prior to the COVID-19 pandemic). That panel dataset contained data in respect of 28,137 individuals that were matched across both quarters and provided weights applicable for Quarter 4 of 2019. The coding of education was the same as for the 2013 panel data. Hence, the same recoding of data was undertaken as for the Quarter 3 to Quarter 4 of 2013 panel dataset. Raw transition rates were derived for each age for the same groupings by gender and broad level of education. The level of education at the beginning of Quarter 3 of 2019 was assumed to remain constant over the ensuing quarter.

4.2.10 Raw transition rates were smoothed using a 9th-order centred moving average. Favour is found in this approach in Smith (1986), Ciecka et. al. (1995) and Krueger (2004). Smoothing is necessary as sample size problems, such as samples being small at older ages, make for irregular transition curves. Moving averages are simple to apply and

personal communication with Krueger confirms that these still provide satisfactory results. Other techniques such as a non-parametric localised regression were not considered.

4.2.11 The smoothed transition rates from Quarter 3 of 2013 to Quarter 4 of 2013, and Quarter 3 of 2019 to Quarter 4 of 2019, were averaged and then applied to each age so as to determine the number of persons who were:

${}^iN_x^i$ = inactive at age x and inactive at age $x+1$

${}^iN_x^a$ = inactive at age x and active at age $x+1$

${}^aN_x^i$ = active at age x and inactive at age $x+1$

${}^aN_x^a$ = active at age x and active at age $x+1$

4.3 National Income Dynamics Study

4.3.1 The National Income Dynamics Study (NIDS) is a face-to-face longitudinal survey of individuals living in South Africa and their households. It is funded by the Department of Planning, Monitoring and Evaluation. The study commenced in 2008 with a nationally representative sample of approximately 28,000 individuals in approximately 7,300 households. The survey was repeated every two years between 2008 and 2017. Five waves of the survey were released over that period.

4.3.2 A set of files was released on request for each wave of NIDS and these files can be combined across waves using a unique identifier for the individual, using the variable name *pid*. For each wave, the *pid* and date of interview was extracted from the *Adult* file using Stata software. This was matched to the *indderived* file. The *indderived* file contained data in respect of gender, year and month of birth, educational level and employment status. The educational levels were broadly similar to those used in the QLFS and were recoded into those with less than a Grade 12 and those with a Grade 12 or higher level of education.

4.3.3 Care had to be taken to match employment status as in the first two waves only three categories were provided but in later waves four categories were provided in the data. Data were matched from wave 1 to wave 2, wave 2 to wave 3 and so on. An individual who was matched across all five waves was treated as a separate individual with their own characteristics and would contribute four separate data points to the survival analysis. The educational level at the beginning of each wave was assumed to apply until the date of the next survey interview.

4.3.4 A survival analysis was conducted on individuals matched across at least two waves using the Kaplan–Meier method. The Kaplan–Meier method is well known and a relatively simple way of calculating survival time. The survival probability across two waves is calculated as the number of individuals who were still employed at the second interview date, having been employed at the first interview date. However, given that the survey dates were approximately two years apart, it is not possible to directly estimate one-year transition rates. Consideration can be given to taking the square root of the two-year transition matrix

derived from the survival analysis undertaken above. However, the square root of a non-scalar 2 times 2 matrix has four square roots if the square of the trace of the matrix does not equal 4 times the determinant of the matrix, and the determinant is non-zero. In addition, the survival rates derived from such an analysis would be unweighted and not representative of the general population. Estimation of one-year transition rates from the NIDS data was therefore considered to be inappropriate.

4.3.5 Cichello et. al. (2014) estimated that between wave 1 and wave 2, the probability of remaining in employment was 70% using post-stratification weights. Projecting the quarterly transition matrix averaged over Quarter 3 to Quarter 4 of 2013 and Quarter 3 to Quarter 4 of 2019 results in a two-year survival rate of approximately 66%. The results are not directly comparable as the estimate made by Cichello et. al. was for ages 20 to 55, whereas our estimate is based on ages 15 to 64.

4.3.6 A further issue that arose is that it was not possible to derive the exact date of exit from employment or the exact date of entry into employment for many individuals, with the result that exposures will be overstated.

4.3.7 Log rank tests applied to the various groupings of gender and educational level confirmed that there were statistically significant differences in survival rates for the groupings adopted (where the failure variable was taken as being not employed at the date of second interview having been employed at the date of first interview).

4.4 Mortality table

4.4.1 Various estimates are available concerning life expectancy at birth in South Africa as shown in Table 1.

TABLE 1. Life expectancy at birth in 2019

Report	Males	Females
World Health Organization	62.2	68.3
Dorrington et al. (2021) ¹	62.4	68.2
Statistics South Africa (2019)	62.0	67.8
Johnson et. al. (2017) ²	62.2	66.1
¹ Rapid Mortality Surveillance Report		
² Thembisa model		

4.4.2 By way of comparison, the South African Life Tables (SALT) 1984/1986 for the white population group provides an estimate of life expectancy of birth of 68.4 years for males and 75.8 years for females. SALT 1984/1986 for the coloured population group provide an estimate of life expectancy of birth of 57.9 years for males and 65.5 years for females.

4.4.3 Some practitioners rely on mortality tables set out in Koch (2022) that are computed according to broad income levels. For high-income earners, Life Table 2 is adopted which is essentially the same as the SALT 1984/1986 for the white population group. For

low-income earners and sometimes for citizens of other African countries claiming from the Road Accident Fund such as in *Langa v Road Accident Fund*,²⁴ Life Table 5 is adopted which is essentially the same as the SALT 1984/1986 for the coloured population group.

4.4.4 If Life Table 2 is applied to those with Grade 12 and higher; and Life Table 5 is applied to those with less than a Grade 12; the mortality rates weighted by population size result in an estimate of life expectancy of 45.9 additional years for males at age 20, and 52.7 additional years for females at age 20. This compares favourably with the World Health Organization (WHO) (2022) estimate of 45.5 additional years for males at age 20 and 51.5 additional years for females at age 20. At age 40, the WHO estimates of future life expectancy are slightly higher than the blended approach noted above. Substituting the WHO rates for all levels of education does not have a material impact on the results. Calculations proceeded using the tables set out in Koch (2022) as these tables are familiar to practitioners and have been cited in various judgments such as Life Table 2 in *Singh and Another v Ebrahim*²⁵ and Life Table 5 in *Seme v Road Accident Fund*.²⁶ Research is however required to examine mortality rates by level of education in South Africa.

4.4.5 Kaplan et. al. (2014) note that education is one of the best predictors of life expectancy, however it is not known whether the relationship is causal. Montez & Berkman (2014) show a difference in life expectancy of between 10 and 12 years between those with less than a high school level of education and those with an advanced degree.

5. MODEL AND NOTATION

5.1 Possible transitions considered in the model are illustrated in Figure 2.

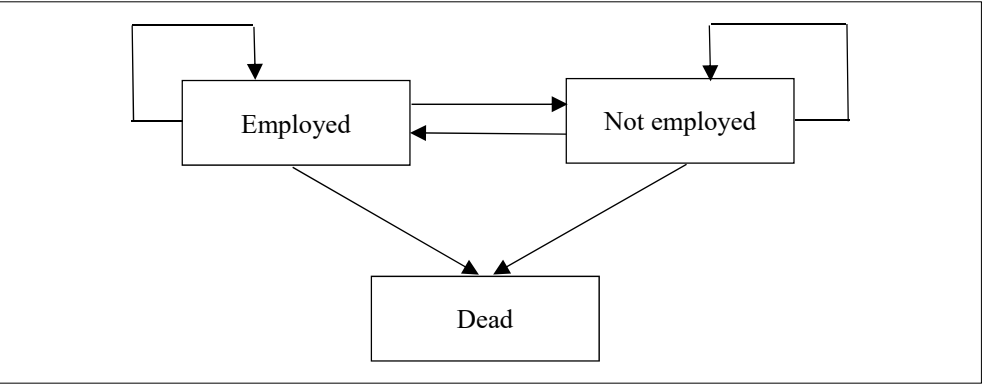


FIGURE 2. Transitions model

5.2 The model adopted is the one period Markov increment-decrement life table (MID₁) for three states as discussed by Krueger (2004). The MID₁ is an important model in the

24 *Langa v Road Accident Fund* (645/2017) [2022] ZAMPMBHC 6

25 *Singh and Another v Ebrahim* (413/09) [2010] ZASCA 145

26 *Seme v Road Accident Fund* (13917/04) [2008] ZAKZHC 79

forensic economic literature used to calculate WLE. The states within this model include the active and inactive states of labour force participation which are annotated by a and i respectively, and the absorbing death state with annotation d . The state of being inactive in this paper means not earning an income or not employed and the state of active means earning an income or employed.

5.3 In the MID₁ WLE model, the labour force status depends only on the current status. The transition probability from a state at age x to a state at age $x+1$ is dependent on the current state, not on historical states (Foster & Skoog, 2004). Hence, for a WLE table, the Markovian assumption implies that the probability that an individual in the given cohort will be active next year is solely dependent on whether the individual was either active or inactive in the current year (Foster & Skoog, 2004). Throughout a synthetic population lifespan, the MID₁ model controls the fluxes between active and inactive labour force participation. Before exiting to the absorbing stage of death, population members of the active and inactive labour force states are considered to migrate back and forth between participating and not-participating in the labour force based on age-specific transition probabilities. The number of people active and inactive in the labour force at each age after x can be used to generate labour force attachment probabilities by age, and the sum of those probabilities by age yields lifetime WLE in total years of labour force attachment. The algebra for computing the MID₁ model in discrete single-age-interval time is presented below.

5.4 We define the transition probability that an individual will be in state t at age $x+1$ exact given that he/she was in state s at age x exact to be ${}^s p_x^t$ where $s \in \{a, i\}$ and $t \in \{a, i, d\}$. According to Skoog et al. (2019) mortality is accounted for within the transition probability and transitions are assumed to occur half-way between ages. In addition, the states are mutually exhaustive such that:

$${}^a p_x^a + {}^a p_x^i + {}^a p_x^d = 1 \quad (3)$$

$${}^i p_x^i + {}^i p_x^a + {}^i p_x^d = 1 \quad (4)$$

5.5 As mortality data by state is unavailable, we assume that:

$${}^a p_x^d = {}^i p_x^d = {}^\bullet p_x^d \quad (5)$$

The values for ${}^\bullet p_x^d$ are obtained from the SALT 1984/1986 as discussed in Section 4.4 and the $\bullet$ denotes either the active or inactive state.

5.6 It should be noted that the age accounted for in population activity data is based on that recorded from the survey and are reported in single-digit values. Hence, the mean value of the age in the data is $x + \frac{1}{2}$. Thus, the survey data should be re-centred to exact ages when the computation of the transition probabilities is completed. This is done by averaging the

surveyed population size data across the range $x \pm \frac{1}{2}$ by combining two ages from survey data.

Hence, we compute ${}^i p_x^i$ and ${}^a p_x^a$ using the following formulae:

$${}^i p_x^i = \left[\frac{{}^i N_{x-1}^i + {}^i N_x^i}{{}^i N_{x-1} + {}^i N_x} \right] * (1 - {}^{\bullet} p_x^d) \quad (6)$$

and

$${}^a p_x^a = \left[\frac{{}^a N_{x-1}^a + {}^a N_x^a}{{}^a N_{x-1} + {}^a N_x} \right] * (1 - {}^{\bullet} p_x^d). \quad (7)$$

5.7 The number of active and inactive labour force survivors at age x exact are calculated recursively using:

$$Total l_x = l_{x-1} (1 - {}^{\bullet} p_x^d) \quad (8)$$

or $x = 19, \dots, 70+$ and we set $Total l_{18}$ = the radix which is obtained from the relevant South African Life Table 1984/1986.

$Total l_x$ denotes the number of survivors (individuals alive) at age x and is also equal to:

$$Total l_x = {}^a l_x + {}^i l_x \quad (9)$$

where ${}^a l_x$ are those active and ${}^i l_x$ are those who are inactive.

5.8 The values of ${}^a l_{19}$ and ${}^i l_{19}$ are computed by the product of the number of individuals alive at age 19 and proportion of individuals in the population who are active and inactive at age 19, respectively, as follows:

$${}^a l_{19} = Total l_{19} * \left(\frac{{}^a N_{19}}{N_{19}} \right) \quad (10)$$

$${}^i l_{19} = Total l_{19} * \left(\frac{{}^i N_{19}}{N_{19}} \right) \quad (11)$$

5.9 For $x > 19$,

$${}^a l_x = {}^a l_{x-1} + {}^i p_{x-1}^a {}^i l_{x-1} - {}^a p_{x-1}^i {}^a l_{x-1} - {}^{\bullet} p_{x-1}^d {}^a l_{x-1} \quad (12)$$

$${}^i l_x = {}^i l_{x-1} + {}^a p_{x-1}^i {}^a l_{x-1} - {}^i p_{x-1}^a {}^i l_{x-1} - {}^{\bullet} p_{x-1}^d {}^i l_{x-1} \quad (13)$$

5.10 Equation (12) above implies that the number of survivors active at exact age x is equal to the number of individuals active at age $x-1$ plus those transitioning from the inactive state

to the active state less those leaving the active state to either the inactive or dead state by age x . Equation (13) illustrates the number of inactive survivors at exact age x which is found using a similar methodology as equation (12).

5.11 It is assumed that transitions occur uniformly throughout the year, thus:

$$Total L_x = \frac{Total l_x + Total l_{x+1}}{2} \quad (14)$$

$$^a L_x = \frac{^a l_x + ^a l_{x+1}}{2} \quad (15)$$

$$^i L_x = \frac{^i l_x + ^i l_{x+1}}{2} \quad (16)$$

where equation (14) represents the number of living years, and equations (15) and (16) represent the active years and inactive years lived by individuals currently aged x respectively.

5.12 The total remaining number of years still to be lived by those aged 70+ are manually set, such that $Total L_{70+}$ is taken directly from the appropriate South African Life Table 1984/1986. $Total L_{70+} = ^i L_{70+}$ as we assume that all individuals are inactive at the “closing” age, thus $^a L_{70+} = 0$.

5.13 Let e_x^* represent the expected years to be lived by an individual aged exact age x and is calculated by adding the total number of active years to be lived throughout all future ages by those currently aged x and dividing it by the number of people alive at age x .

$$e_x^* = \frac{\sum_x^{70+} Total L_x}{Total l_x} \quad (17)$$

5.14 Based on Foster & Skoog (2004), WLE at age x is the average number of years that a cohort of age x will be in the labour force, before retiring permanently or dying. The expected remaining inactive years to be lived by an individual currently aged x exact and the expected remaining active years to be lived by an individual currently aged x is given in equation (18) and equation (19):

$$e_x^i = \frac{\sum_x^{70+} ^i L_x}{Total l_x} \quad (18)$$

$$e_x^a = \frac{\sum_x^{70+} ^a L_x}{Total l_x} \quad (19)$$

5.15 It follows that:

$$e_x^\bullet = e_x^a + e_x^i \quad (20)$$

5.16 If the radix values are changed such that ${}^a l_x = {}^\bullet l_x$ and ${}^i l_x = 0$, then an estimate can be made of WLE conditional on a commencement status of active at age x . Similarly, if the radix values are changed such that ${}^i l_x = {}^\bullet l_x$ and ${}^a l_x = 0$, then an estimate can be made of WLE conditional on a commencement status of inactive at age x .

5.17 The estimated contingency deductions set out in the Appendices have been determined on the basis of a commencement status of active at age x . In addition, the contingency deductions only hold if income remains constant in real terms from age x until retirement at age 65. The contingency deduction has been estimated as an approximation to:

$$\text{Contingency deduction at age } x = 1 - \frac{\int_x^{65} {}_t p'_x v^t dt}{\int_x^{65} {}_t p_x v^t dt} \quad (21)$$

where ${}_t p_x$ is determined on a mortality only basis and ${}_t p'_x$ is determined on a mortality and active status basis conditional on a commencement status of active. A net discount rate of 2.5% per annum compound is assumed in all calculations and represents the net rate of investment return after taxation and inflation.

6. RESULTS AND DISCUSSION

6.1 Results

6.1.1 Appendix A reflects results for females with less than a Grade 12 level of education, Appendix B reflects results for females with a Grade 12 level of education or greater, Appendix C reflects results for males with less than a Grade 12 level of education, and Appendix D reflects results for males with a Grade 12 level of education or greater.

6.1.2 Each appendix shows details of transition probabilities, active life expectancy and inactive life expectancy from age 20 to age 65. In addition, an estimate is provided of the contingency deduction that would be applicable to an individual who is employed and is injured from age 20 to age 60, if normal retirement is assumed to be at age 65. With respect to each table of contingency deductions, earnings are assumed to increase in line with inflation only until retirement at age 65.

6.1.3 From age 20 to age 40, the ratio of active life expectancy to total life expectancy is around 30% for females with less than a Grade 12, compared to 60% for males with at least a Grade 12. Active WLE for males with at least a Grade 12 exceeded those for males with less than a Grade 12. The same pattern holds for females. Females with at least a Grade 12 had higher working life expectancies than males with less than a Grade 12.

6.1.4 General contingency deductions are lowest for males with at least a Grade 12 level of education, with the deduction being 25% or less between age 27 and age 47. At older ages the contingency deductions counter the rule of thumb that shorter future periods should attract lower contingency deductions. This could be due to factors such as

early retirement, however more data are required at older ages in order to confirm this. Our results are nevertheless consistent with those in the Ogden tables where higher contingency deductions are applicable at older ages.

6.2 Discussion

6.2.1 Compensation for future loss of income in South Africa is primarily a function of earnings. Higher income earners will receive more compensation than lower income earners for the same injury. The compensation system for Road Accident Fund claims is not redistributive. The findings in this paper would arguably exacerbate the situation where the more educated and by association higher income earners would attract lower contingency deductions. The defined benefit system of compensation envisaged in the Road Accident Benefit Scheme Bill would have to some extent narrowed the gap in compensation between high-income earners and low-income earners. It is unclear if the courts would make a distinction between contingency deductions for males compared to contingency deductions for females, despite the significant gap in WLE estimated in this paper.

6.2.2 In more advanced jurisdictions such as the United States that have considered such issues, Ben-Zion & Visser (2021) note that numerous implementation questions arise and to date there are no appellate decisions illuminating the implementation of California Senate Bill 41 that provides that:

Estimations, measures, or calculations of past, present, or future damages for lost earnings or impaired earning capacity resulting from personal injury or wrongful death shall not be reduced based on race, ethnicity, or gender.

6.2.3 Ireland (2010) notes that most of the difference between male and female WLE can be explained by the role that females play in child care and elder care. The import of this is that some forensic economists use male WLE for females who have shown consistent labour force attachment.

6.2.4 Palamuleni (2007) constructed what he refers to as working life tables for the South African population based on census data for 1996 and 2001. However, the estimates derived are representative of the expectation of economically active life and are not comparable to the results in this paper. In particular, based on the 2001 census, Palamuleni (2007) obtains an estimate of 36 years in active status and 8 years in inactive status for a male age 15. His estimates are therefore of economically active life where an economically active individual is one who is either employed or unemployed but is trying to obtain employment. The results do not measure time earning an income, but rather time earning an income plus time available for employment for those who want employment.

6.2.5 Lower levels of education are correlated with lower active working life expectancies, but the results must not be interpreted as causative. For example, better educated individuals tend to be less likely to be unemployed, but this could be due to ability in that more intelligent individuals are simultaneously more likely to obtain more education and to have more successful careers. Hence, providing additional education will not necessarily improve an individual's labour market prospects.

6.2.6 Secondary to the development of WLE tables, it is important to understand the relationship between education and life expectancy in South Africa. In addition, more sophisticated models may be developed that examine differences in mortality between active and inactive states.

6.2.7 The WLE tables produced in this paper summarise the average behaviour of individuals grouped in the same cohort. However, care must be taken when forecasting the labour force behaviour of an individual. This is especially important when the individual in question is not an ideal representative of the class considered. This limitation arises due to the heterogeneity in the class, introducing bias into the WLE of an individual (Foster & Skoog, 2004). Nevertheless, the results in this paper reflect the economic realities of South Africa and could find application in many claims for future loss of income.

6.2.8 Table 2 and Table 3 provide a comparison between active WLE as a percentage of total life expectancy derived from this paper and the corresponding results derived by Smith (1986). Smith (1986) provided results for those with less than high school, high school to 14 years of education and individuals with 15 or more years of education.

TABLE 2. Active WLE as a percentage of total life expectancy
(lowest education category)

Results from	This study	Smith (1986)
30-year-old males in lowest education category	54%	59%
30-year-old females in lowest education category	32%	32%

TABLE 3. Active WLE as a percentage of total life expectancy
(highest education category)

Results from	This study	Smith (1986)
30-year-old males in highest education category	62%	75%
30-year-old females in highest education category	46%	49%

6.2.9 Table 4 provides a comparison between the contingency deductions applicable for various ages for individuals who would have retired at age 65 derived from this paper and the corresponding results in the Ogden tables in the United Kingdom. It must be noted however that the Ogden tables make a distinction between non-disabled lives and disabled lives. The results below are in respect of non-disabled lives.

TABLE 4. Contingency deductions for various ages

Educational level Grade 12 or higher in South Africa/GCSE A level in UK	This study	Ogden tables
30-year-old male employed at accident date	23%	10%
40-year-old male employed at accident date	23%	13%
50-year-old male employed at accident date	28%	17%

7. LIMITATIONS

7.1 Ideally, a large dataset such as the Current Population Survey produced by the Census Bureau in the United States would permit a more detailed analysis of WLE by more granular levels of education. The choice of less than Grade 12 and Grade 12 or higher provided a convenient split of the population between two groups of similar size once weightings were applied (approximately 21.4 million people in the former group and 19.3 million people in the latter group at Quarter 2 of 2022). Nevertheless, dividing the data into two distinct groups could be indicative of occupations for which a certain level of competency or training is required.

7.2 The WLE tables assume that the probabilities of transition estimated over a one-year period will remain unchanged in the future. The assumed stability of probabilities of transition mirror those assumed with respect to the stability of mortality over time embedded in cross sectional population life tables. However, the framework set up in this paper will allow for annual updates of the transition rates which in turn will provide a useful measure of the success of labour market policies. In addition, the model easily makes allowance for exploratory analysis such as the impact on WLE and consequently contingency deductions should transition probabilities for certain age groups improve or worsen.

7.3 There are a number of factors that can have an impact on finding employment other than the level of education of an individual, such as prior work experience, an individual's network, their province of residence and marital status. Given the memoryless property of the Markov process, these factors were not considered in this paper, but this could be an area for future research.

7.4 Shibata (2019) notes that a first-order Markov Chain model does not cater for differences in unobservable characteristics such as human capital and observable characteristics such as labour force histories. Given the relatively small sample sizes available for the 2013 and 2019 panels, further stratification of the sample by length of current employment for example was not feasible. Should Statistics South Africa increase the size of their panel survey, this may become possible.

7.5 As with any panel data from a statistical agency, the data are subject to classification error, where participants misreport their labour market status. No adjustment was made for classification errors in this paper. As the WLE were generated from sample data, a further area of research would be to examine the impact of sample variation.

7.6 The paper makes no distinction between formal sector employment and informal sector employment, or measuring transitions between formal sector and informal sector employment. Further research could be conducted using the techniques in this paper. Alternatively econometric models could be used to predict the probability of transition between various states taking into account factors such as age, occupation, marital status, number of children

and gender. Consideration can also be given to determining deductions by broad income bands.

8. CONCLUSION

8.1 Despite various limitations identified in the data that do not permit a full implementation of the model, empirical data shows that WLE for females is less than males irrespective of level of education. Consequently, the implied contingency deduction by broad level of education would be higher for females compared to males. Consideration could be given to using male rates for females who have shown consistent labour force attachment. Legal arguments around differential contingency deductions between males and females have not materialised as to date there have been no reliable WLE tables.

8.2 Out of the four broad classification groups of the working population, males with a Grade 12 or higher had the highest WLE. More data are required so as to stratify the population into more detailed educational levels, but given the very low proportion of degreed individuals in South Africa, this may not be feasible. Unfortunately, subjective adjustments may then be required for degreed or higher degreed individuals. In line with international literature, it is expected that an individual with a degree or higher degree would have a higher WLE and hence lower general contingency deductions would probably be indicated.

8.3 This paper highlights the importance of extending the work done by statistical agencies. The NIDS dataset followed up participants roughly every two years. Ideally, Statistics South Africa should release an annual panel dataset which is reweighted to the population. This dataset could be used to test the one-year rates derived from projecting quarterly transition rates. A significantly larger data set could also give rise to a more granular analysis.

8.4 This paper highlights the importance of measuring WLE using a Markov Chain model and it is an essential tool, not only in the compensation space, but in broader planning and decision-making. A more detailed analysis is required of the impact of education on life expectancy and, in turn, education can be used as a lever to shape health policy. Statistical agencies should strive to produce tables of WLE along with publications such as the mid-year population estimate. This can clearly indicate trends in employment by age group and education levels.

ACKNOWLEDGMENTS

The authors thank Desiree Manamela and Ndivhuwo Gangazhe of StatsSA for their assistance in securing an additional panel data file. One of the authors is sponsored by the National Research Foundation of South Africa (Grant Number 142849).

REFERENCES

- Abele, JR & Richards, H (1999). *Life and worklife expectancies*. Tuscon, AZ: Lawyers and Judges Publishing Company, Inc.
- Ben-Zion, B & Visser, M (2021). Update to assessing economic damages in personal injury and wrongful death litigation: The State of California. *Journal of Forensic Economics* **29**(2), 229–35
- Bloomfield, DSF & Haberman, S (1990). Work time lost to sickness, unemployment and stoppages: Measurement and application. *Journal of the Institute of Actuaries* **117**(3), 533–95
- Boberg, PQR (1964). Deductions from gross damages in actions for wrongful death. *S. African LJ* **81**, 194–225
- Cichello, P, Leibbrandt, M & Woolard, I (2014). Winners and losers: South African labour-market dynamics between 2008 and 2010. *Development Southern Africa* **31**(1), 65–84
- Ciecka, J, Donley, T & Goldman, J (1995). A Markov process model of work-life expectancies based on labor-force activity in 1992–93. *Journal of Legal Economics*, 1995, **5**(3), 17–41
- Corbett, MM, Gauntlett, JJ & Buchanan, JL (1995). *The quantum of damages in bodily and fatal injury cases*. Juta and Company Limited, Cape Town
- Dorrington RE, Bradshaw D, Laubscher R & Nannan N (2021). Rapid mortality surveillance report 2019 & 2020. South African Medical Research Council, Cape Town
- Du Pasquier, L (1913). Mathematical theory of disability insurance. *Zeitschrift für Schweizerische Statistik* **49**, 161–209
- Du Plessis, HLM (2012). The divergent approaches of English and South African courts, when considering actuarial expert testimony in the matter of an award for damages for future loss of earnings after a damage-causing event. *Annals of Actuarial Science* **6**(1), 5–22
- Foster, EM & Skoog, GR (2004). The Markov assumption for worklife expectancy. *Journal of Forensic Economics* **17**(2), 167–83
- Government Actuary's Department (2022). *Actuarial tables with explanatory notes for use in personal injury and fatal accident cases*, 8th edition. The Stationery Office, London
- Hoem, JM & Fong, MS (1976). A Markov Chain model of working life tables. Copenhagen University Laboratory of Actuarial Mathematics, Working Paper No. 2
- Hoem, JM (1977). A Markov Chain model of working life tables. *Scandinavian Actuarial Journal* **1977**(1), 1–20
- Ireland, TR (2010). Why Markov process worklife expectancy tables are usually superior to the LPE method. *Journal of Legal Economics* **16**(2), 95–110
- Johnson LF, May MT, Dorrington RE, Cornell M, Boule A, Egger M & Davies MA (2017). Estimating the impact of antiretroviral treatment on adult mortality trends in South Africa: A mathematical modelling study. *PLoS Medicine* **14**(12), e1002468
- Kaplan, RM, Spittel, ML & Zeno, TL (2014). Educational attainment and life expectancy. *Policy Insights from the Behavioral and Brain Sciences* **1**(1), 189–94
- Koch, RJ (1984). *Damages for lost income*. Juta & Company Limited, Cape Town
- Koch, RJ (2022). *The Quantum Yearbook*. Van Zyl, Rudd & Associates. Gqeberha
- Krueger, KV (2004). Tables of inter-year labour force status of the U.S. Population (1998–2004) to operate the Markov Chain model of worklife expectancy. *Journal of Forensic Economics* **17**(3), 313–81

- Millimet, DL, Nieswiadomy, M, Ryu, H & Slottje, D (2003). Estimating worklife expectancy: econometric approach. *Journal of Econometrics* 113, 83–113
- Montez, JK & Berkman, LF (2014). Trends in the educational gradient of mortality among US adults aged 45 to 84 years: Bringing regional context into the explanation. *American Journal of Public Health* 104(1), e82–e90
- Palamuleni, ME (2007). Working life tables for South Africa (1994–2001). *African Population Studies* 22(2)
- Samaniego, B & Viegelahn, C (2021). Estimating labour market transitions from labour force surveys: The case of Viet Nam, ILO Working paper 35 (Geneva, ILO)
- Schoen, R & Woodrow, K (1980). Labour force status life tables for the United States (1972) *Demography* 17, 297–323
- Shibata, MI (2019). Labour market dynamics: A hidden Markov Chain model. International Monetary Fund
- Skoog, GR & Ciecka, JE (2001). The Markov (increment-decrement) model of labor force activity: New results beyond worklife expectancies. *Journal of Legal Economics* 11(1), 1–21
- Skoog, GR, Ciecka, JE & Krueger, KV (2011). The Markov process model of labour force activity: Extended tables of central tendency, shape, percentile points, and bootstrap standard errors. *Journal of Forensic Economics* 22, 165–229
- Skoog, GR, Ciecka, JE & Krueger, KV (2019) The Markov Chain model of labour force activity (2012–17): Extended tables of central tendency, shape, percentile points, and bootstrap standard errors. *Journal of Forensic Economics* 28, 15–108
- Smith, SJ (1982). Tables of working life: The increment-decrement model (Vol. 2135). US Department of Labor, Bureau of Labor Statistics
- Smith, SJ (1986). Worklife estimates: The effects of race and education: U.S. Department of Labour, Bureau of Labor Statistics
- South African Life Tables 1984–1986; Report No. 02-06-04
- Southern Africa Labour and Development Research Unit. National Income Dynamics Study (2017), Wave 5 [dataset]. Version 1.0.0 Pretoria: Department of Planning, Monitoring, and Evaluation. <https://doi.org/10.25828/fw3h-v708>
- Southern Africa Labour and Development Research Unit. National Income Dynamics Study (2014–2015), Wave 4 [dataset]. Version 2.0.0. Pretoria: Department of Planning, Monitoring, and Evaluation. <https://doi.org/10.25828/f4ws-8a78>
- Southern Africa Labour and Development Research Unit. National Income Dynamics Study (2012), Wave 3 [dataset]. Version 3.0.0. Pretoria: SA Presidency. <https://doi.org/10.25828/7pgq-q106>
- Southern Africa Labour and Development Research Unit. National Income Dynamics Study (2010–2011), Wave 2 [dataset]. Version 4.0.0. Pretoria: SA Presidency. <https://doi.org/10.25828/j1h1-5m16>
- Southern Africa Labour and Development Research Unit. National Income Dynamics Study (2008), Wave 1 [dataset]. Version 7.0.0. Pretoria: SA Presidency. <https://doi.org/10.25828/e7w9-m033>
- Statistics South Africa (2014). Quarterly Labour Force Survey Panel Data. [Online]
- Statistics South Africa (2019). Mid-year population estimates 2019. Statistics South Africa, Pretoria

- Verrall, R, Haberman, S & Butt, Z (2005). An investigative study on current practice of estimating the loss of earnings in personal injury claims in England and Wales: the Ogden Tables and contingencies other than mortality (Vol. 1). Working Paper
- Visser, PJ & Potgieter, JM (2004). *Law of damages through the cases*. Juta and Company Limited, Cape Town
- Watt, G, Laing, G & Douglas, S (2019). Work life expectancy and loss of future earnings: a review. *Journal of New Business Ideas & Trends* **17**(2), 1–10
- Wolfbein, SL (1949). The length of working life. *Population Studies* **3**(3), 286–94
- World Health Organization, (2022). Life expectancy and Healthy life expectancy – Data by country. *Glob Heal Obs*. Published online 2022. <https://www.who.int/data/gho>

APPENDIX A1
Females with less than Grade 12

Age	Population counts at age x			Population transitions age x to x + 1				Probability transitions age x to x + 1		
x	Population _x N _x	Inactive _x iN _x	Active _x a ^a N _x	Inactive _x Inactive _{x+1} iN ⁱ _x	Inactive _x Active _{x+1} iN ^a _x	Active _x Inactive _{x+1} a ⁱ N _x	Active _x Active _{x+1} a ^a N _x	Living _x Dead _{x+1} p ^d _x	Inactive _x Inactive _{x+1} p ⁱ _x	Active _x Active _{x+1} a ^a p _x
20	166,932	158,717	8,215	146,384	12,333	4,847	3,368	0.00133	0.90073	0.39840
21	174,839	164,286	10,553	148,635	15,651	5,570	4,983	0.00146	0.91203	0.44429
22	242,764	219,782	22,982	194,999	24,783	10,742	12,240	0.00160	0.89329	0.51275
23	188,023	169,367	18,656	146,811	22,556	7,950	10,706	0.00173	0.87683	0.55012
24	174,058	147,412	26,646	125,419	21,993	12,545	14,101	0.00187	0.85777	0.54656
25	186,324	143,942	42,382	121,101	22,841	18,971	23,411	0.00199	0.84443	0.54235
26	185,843	151,020	34,823	126,630	24,390	14,970	19,853	0.00211	0.83810	0.55920
27	211,898	170,867	41,031	140,204	30,663	17,054	23,977	0.00223	0.82712	0.57653
28	222,184	171,399	50,785	139,198	32,201	20,738	30,047	0.00236	0.81441	0.58701
29	189,328	146,415	42,913	118,047	28,368	16,595	26,318	0.00247	0.80742	0.60008
30	207,012	148,662	58,350	118,926	29,736	22,047	36,303	0.00259	0.80101	0.61680
31	232,851	172,452	60,399	135,768	36,684	22,246	38,153	0.00272	0.79100	0.62530
32	253,630	164,808	88,822	127,023	37,785	30,827	57,995	0.00288	0.77695	0.64248
33	226,410	148,590	77,820	113,737	34,853	25,187	52,633	0.00308	0.76586	0.66183
34	210,366	151,082	59,284	114,187	36,895	18,546	40,738	0.00331	0.75806	0.67877
35	198,287	130,482	67,805	97,636	32,846	19,670	48,135	0.00359	0.74961	0.69679
36	215,258	140,760	74,498	104,891	35,869	20,567	53,931	0.00390	0.74375	0.71445
37	214,662	154,010	60,652	114,514	39,496	16,029	44,623	0.00425	0.74117	0.72612
38	216,567	146,980	69,587	109,181	37,799	17,123	52,464	0.00462	0.73976	0.74201
39	229,131	152,591	76,540	113,392	39,199	18,010	58,530	0.00502	0.73924	0.75576
40	205,867	104,211	101,656	78,028	26,183	24,156	77,500	0.00545	0.74134	0.75921
41	208,593	127,108	81,485	96,872	30,236	20,601	60,884	0.00590	0.75164	0.75116
42	209,361	125,020	84,341	96,047	28,973	22,143	62,198	0.00638	0.76028	0.73750
43	166,258	107,871	58,387	81,587	26,284	15,067	43,320	0.00689	0.75748	0.73420
44	171,400	105,407	65,993	78,378	27,029	16,428	49,565	0.00742	0.74446	0.74124
45	187,825	113,708	74,117	86,643	27,065	18,543	55,574	0.00798	0.74711	0.74441
46	188,971	107,227	81,744	82,125	25,102	19,672	62,072	0.00857	0.75733	0.74835
47	222,750	149,954	72,796	115,112	34,842	17,614	55,182	0.00918	0.75988	0.75176
48	184,545	105,549	78,996	81,154	24,395	20,145	58,851	0.00981	0.76062	0.74387
49	201,602	127,155	74,447	98,364	28,791	18,872	55,575	0.01047	0.76337	0.73791
50	147,245	71,297	75,948	55,219	16,078	18,125	57,823	0.01116	0.76527	0.74558

Age	Population counts at age x			Population transitions age x to $x+1$				Probability transitions age x to $x+1$		
x	Population _{x} N_x	Inactive _{x} iN_x	Active _{x} aN_x	Inactive _{x} iN_x^i	Inactive _{$x+1$} iN_{x+1}^i	Active _{x} aN_x^a	Active _{$x+1$} aN_{x+1}^a	Living _{x} p_x^d	Inactive _{$x+1$} p_x^i	Active _{$x+1$} p_x^a
51	174,403	96,541	77,862	75,636	20,905	19,385	58,477	0.01189	0.77038	0.74713
52	160,671	98,471	62,200	79,740	18,731	15,316	46,884	0.01268	0.78665	0.74270
53	205,412	117,819	87,593	97,466	20,353	22,447	65,146	0.01363	0.80813	0.73770
54	162,714	101,862	60,852	85,081	16,781	14,743	46,109	0.01445	0.81896	0.73864
55	154,654	93,795	60,859	79,709	14,086	15,751	45,108	0.01545	0.82923	0.73788
56	164,732	116,857	47,875	100,936	15,921	13,411	34,464	0.01652	0.84338	0.71971
57	171,461	111,942	59,519	98,727	13,215	16,091	43,428	0.01768	0.85723	0.71247
58	169,998	116,677	53,321	104,621	12,056	15,855	37,466	0.01891	0.87264	0.70333
59	159,285	111,459	47,826	101,865	9,594	14,602	33,224	0.02023	0.88679	0.68474
60	175,954	145,070	30,884	134,654	10,416	10,517	20,367	0.02160	0.90208	0.66615
61	158,586	145,513	13,073	135,536	9,977	4,676	8,397	0.02302	0.90842	0.63932
62	154,872	137,566	17,306	129,852	7,714	6,376	10,930	0.02445	0.91458	0.62064
63	154,475	145,780	8,695	138,204	7,576	3,557	5,138	0.02588	0.92155	0.60199
64	145,152	136,357	8,795	129,976	6,381	3,694	5,101	0.02731	0.92457	0.56945
65	156,376	149,728	6,648	142,721	7,007	2,792	3,856	0.02884	0.92571	0.56326

APPENDIX A2
Females with less than Grade 12

Age x	Probability transitions age x to $x + 1$				Stationary population in each status			Person years lived in each status		
	Inactive _{x} Inactive _{$x+1$} ${}^i p^i_x$	Active _{x} Active _{$x+1$} ${}^a p^a_x$	Inactive _{x} Inactive _{$x+1$} ${}^i p^i_x$	Active _{x} Active _{$x+1$} ${}^a p^a_x$	Total I_x	Inactive i^i_x	Active a^a_x	Total L_x	Inactive i^i_x	Active a^a_x
20	0.90073	0.09795	0.60028	0.39840	92,923	82,106	10,817	92,861	81,277	11,584
21	0.91203	0.08651	0.55425	0.44429	92,800	80,448	12,351	92,732	80,333	12,399
22	0.89329	0.10511	0.48565	0.51275	92,664	80,217	12,447	92,590	78,959	13,631
23	0.87683	0.12144	0.44815	0.55012	92,516	77,702	14,814	92,436	76,236	16,200
24	0.85777	0.14037	0.45157	0.54656	92,356	74,770	17,585	92,269	73,423	18,846
25	0.84443	0.15357	0.45566	0.54235	92,183	72,077	20,107	92,091	71,051	21,040
26	0.83810	0.15979	0.43869	0.55920	91,999	70,026	21,974	91,902	69,177	22,725
27	0.82712	0.17065	0.42124	0.57653	91,805	68,328	23,477	91,703	67,366	24,336
28	0.81441	0.18324	0.41064	0.58701	91,600	66,405	25,195	91,492	65,416	26,077
29	0.80742	0.19011	0.39745	0.60008	91,384	64,427	26,958	91,271	63,580	27,691
30	0.80101	0.19640	0.38061	0.61680	91,159	62,734	28,425	91,041	61,902	29,139
31	0.79100	0.20628	0.37198	0.62530	90,923	61,069	29,853	90,799	60,240	30,559
32	0.77695	0.22017	0.35464	0.64248	90,675	59,410	31,264	90,544	58,328	32,216
33	0.76586	0.23106	0.33510	0.66183	90,413	57,246	33,167	90,274	56,102	34,173
34	0.75806	0.23863	0.31791	0.67877	90,135	54,957	35,178	89,986	53,901	36,085
35	0.74961	0.24680	0.29962	0.69679	89,837	52,844	36,992	89,676	51,770	37,905
36	0.74375	0.25235	0.28165	0.71445	89,514	50,696	38,818	89,340	49,668	39,672
37	0.74117	0.25459	0.26963	0.72612	89,165	48,639	40,526	88,976	47,808	41,168
38	0.73976	0.25562	0.25337	0.74201	88,787	46,977	41,810	88,582	46,161	42,421
39	0.73924	0.25574	0.23922	0.75576	88,377	45,345	43,031	88,155	44,580	43,575
40	0.74134	0.25321	0.23534	0.75921	87,933	43,815	44,118	87,693	43,340	44,354
41	0.75164	0.24246	0.24294	0.75116	87,454	42,865	44,589	87,196	42,958	44,238
42	0.76028	0.23334	0.25612	0.73750	86,938	43,051	43,887	86,661	43,511	43,149
43	0.75748	0.23563	0.25891	0.73420	86,383	43,971	42,412	86,086	44,130	41,956
44	0.74446	0.24812	0.25134	0.74124	85,788	44,288	41,500	85,470	43,845	41,625
45	0.74711	0.24491	0.24761	0.74441	85,152	43,401	41,750	84,812	43,082	41,729
46	0.75733	0.23410	0.24309	0.74835	84,472	42,763	41,709	84,110	42,644	41,466
47	0.75988	0.23094	0.23906	0.75176	83,748	42,525	41,223	83,364	42,347	41,017
48	0.76062	0.22957	0.24631	0.74387	82,979	42,169	40,811	82,572	42,148	40,425
49	0.76337	0.22616	0.25162	0.73791	82,165	42,126	40,039	81,735	42,179	39,556
50	0.76527	0.22357	0.24326	0.74558	81,305	42,232	39,073	80,851	42,028	38,823

Age x	Probability transitions age x to $x+1$				Stationary population in each status			Person years lived in each status		
	Inactive _{x} Inactive _{$x+1$} ${}^i p_x^i$	Inactive _{x} Active _{$x+1$} ${}^i p_x^a$	Active _{x} Inactive _{$x+1$} ${}^a p_x^i$	Active _{x} Active _{$x+1$} ${}^a p_x^a$	Total I_x	Inactive ${}^i I_x$	Active ${}^a I_x$	Total L_x	Inactive ${}^i L_x$	Active ${}^a L_x$
51	0.77038	0.21773	0.24097	0.74713	80,397	41,824	38,574	79,919	41,670	38,250
52	0.78665	0.20067	0.24462	0.74270	79,441	41,515	37,926	78,938	41,725	37,212
53	0.80813	0.17824	0.24867	0.73770	78,434	41,935	36,499	77,900	42,450	35,449
54	0.81896	0.16659	0.24691	0.73864	77,365	42,966	34,400	76,806	43,323	33,483
55	0.82923	0.15532	0.24667	0.73788	76,247	43,680	32,567	75,658	43,967	31,691
56	0.84338	0.14009	0.26377	0.71971	75,069	44,254	30,815	74,449	44,853	29,596
57	0.85723	0.12509	0.26985	0.71247	73,829	45,451	28,377	73,176	46,036	27,141
58	0.87264	0.10845	0.27776	0.70333	72,524	46,620	25,904	71,838	47,249	24,589
59	0.88679	0.09298	0.29503	0.68474	71,152	47,877	23,275	70,432	48,600	21,832
60	0.90208	0.07632	0.31224	0.66615	69,713	49,324	20,389	68,960	50,092	18,868
61	0.90842	0.06856	0.33767	0.63932	68,207	50,860	17,347	67,422	51,460	15,962
62	0.91458	0.06097	0.35491	0.62064	66,637	52,059	14,577	65,822	52,423	13,399
63	0.92155	0.05256	0.37213	0.60199	65,007	52,786	12,221	64,166	52,990	11,176
64	0.92457	0.04812	0.40324	0.56945	63,325	53,193	10,131	62,460	53,230	9,230
65	0.92571	0.04545	0.40790	0.56326	61,595	53,266	8,329	60,707	52,986	7,720

APPENDIX A3
Females with less than Grade 12

Age		Various whole life expectancies			Present value of 1 to age 65	
x	Life expectancy	Inactive life expectancy	Active life expectancy	Mortality only basis	Active basis	Implied contingency deduction
20	50.32	35.25	15.06	25.14	8.93	64%
21	49.38	34.43	14.96	24.79	8.88	64%
22	48.45	33.61	14.84	24.43	8.93	63%
23	47.53	32.81	14.72	24.07	9.00	63%
24	46.61	32.04	14.57	23.70	9.05	62%
25	45.70	31.30	14.39	23.33	9.09	61%
26	44.79	30.59	14.19	22.94	9.10	60%
27	43.88	29.91	13.98	22.55	9.10	60%
28	42.98	29.24	13.74	22.16	9.08	59%
29	42.08	28.59	13.49	21.75	9.04	58%
30	41.18	27.96	13.22	21.34	8.98	58%
31	40.29	27.36	12.93	20.91	8.90	57%
32	39.40	26.77	12.63	20.48	8.81	57%
33	38.51	26.20	12.31	20.04	8.69	57%
34	37.63	25.66	11.97	19.59	8.56	56%
35	36.75	25.14	11.61	19.13	8.39	56%
36	35.88	24.65	11.23	18.67	8.20	56%
37	35.02	24.19	10.82	18.19	7.99	56%
38	34.17	23.76	10.41	17.71	7.76	56%
39	33.32	23.35	9.98	17.22	7.50	56%
40	32.49	22.96	9.53	16.73	7.23	57%
41	31.66	22.59	9.08	16.23	6.93	57%
42	30.85	22.23	8.62	15.71	6.63	58%
43	30.04	21.87	8.18	15.19	6.34	58%
44	29.25	21.50	7.74	14.67	6.05	59%
45	28.46	21.15	7.31	14.13	5.75	59%
46	27.69	20.81	6.88	13.58	5.44	60%
47	26.92	20.48	6.44	13.03	5.12	61%
48	26.17	20.16	6.01	12.46	4.80	61%
49	25.42	19.85	5.57	11.88	4.47	62%
50	24.69	19.54	5.15	11.29	4.14	63%

Age	Various whole life expectancies			Present value of 1 to age 65		
<i>x</i>	Life expectancy	Inactive life expectancy	Active life expectancy	Mortality only basis	Active basis	Implied contingency deduction
51	23.96	19.24	4.72	10.68	3.80	64%
52	23.24	18.94	4.30	10.06	3.45	66%
53	22.53	18.65	3.88	9.43	3.10	67%
54	21.84	18.36	3.47	8.77	2.76	69%
55	21.15	18.06	3.09	8.11	2.43	70%
56	20.47	17.76	2.71	7.42	2.10	72%
57	19.81	17.45	2.36	6.71	1.78	73%
58	19.16	17.13	2.03	5.98	1.48	75%
59	18.52	16.80	1.72	5.23	1.20	77%
60	17.89	16.45	1.44	4.44	0.94	79%

APPENDIX B1
Females with Grade 12 or more

Age x	Population counts at age x			Population transitions age x to $x + 1$				Probability transitions age x to $x + 1$		
	Population _{x} N_x	Inactive _{x} iN_x	Active _{x} aN_x	Inactive _{$x+1$} iN_{x+1}	Active _{$x+1$} aN_{x+1}	Inactive _{$x+1$} iN_{x+1}	Active _{$x+1$} aN_{x+1}	Living _{$x+1$} p^d_{x+1}	Inactive _{$x+1$} p^i_x	Active _{$x+1$} p^a_x
20	311,577	274,093	37,484	184,380	89,713	18,741	18,743	0.00062	0.63571	0.48098
21	308,672	272,849	35,823	208,289	64,560	15,091	20,732	0.00065	0.71747	0.53815
22	312,939	257,760	55,179	220,747	37,013	18,471	36,708	0.00067	0.80803	0.63078
23	344,540	250,665	93,875	208,001	42,664	33,245	60,630	0.00069	0.84270	0.65259
24	347,291	256,696	90,595	208,066	48,630	27,520	63,075	0.00071	0.81948	0.67012
25	355,700	228,039	127,661	179,571	48,468	32,628	95,033	0.00073	0.79910	0.72388
26	334,522	216,041	118,481	167,939	48,102	29,245	89,236	0.00075	0.78195	0.74807
27	331,237	186,753	144,484	142,164	44,589	31,769	112,715	0.00077	0.76928	0.76738
28	331,537	183,827	147,710	137,676	46,151	28,302	119,408	0.00080	0.75454	0.79378
29	293,474	161,277	132,197	119,679	41,598	23,668	108,529	0.00083	0.74511	0.81366
30	273,638	130,937	142,701	95,961	34,976	23,215	119,486	0.00086	0.73732	0.82874
31	290,648	159,563	131,085	117,742	41,821	20,672	110,413	0.00090	0.73498	0.83895
32	298,406	148,442	149,964	109,333	39,109	23,445	126,519	0.00094	0.73655	0.84223
33	260,086	119,536	140,550	87,398	32,138	20,455	120,095	0.00099	0.73340	0.84804
34	241,083	88,021	153,062	64,409	23,612	22,392	130,670	0.00105	0.73063	0.85317
35	266,479	114,775	151,704	85,186	29,589	21,006	130,698	0.00113	0.73683	0.85663
36	257,786	103,896	153,890	78,748	25,148	19,694	134,196	0.00122	0.74878	0.86576
37	232,986	105,516	127,470	79,197	26,319	16,188	111,282	0.00132	0.75324	0.87132
38	244,045	105,006	139,039	81,534	23,472	18,152	120,887	0.00143	0.76239	0.86990
39	227,215	99,336	127,879	75,653	23,683	16,201	111,678	0.00157	0.76803	0.86994
40	221,648	76,267	145,381	57,616	18,651	17,227	128,154	0.00172	0.75761	0.87616
41	235,799	87,765	148,034	65,763	22,002	16,560	131,474	0.00190	0.75073	0.88317
42	221,891	77,220	144,671	58,956	18,264	15,253	129,418	0.00212	0.75434	0.88943
43	201,461	82,687	118,774	62,596	20,091	11,217	107,557	0.00236	0.75834	0.89740
44	169,596	57,292	112,304	42,452	14,840	10,113	102,191	0.00265	0.74847	0.90529
45	171,544	66,420	105,124	49,850	16,570	9,894	95,230	0.00296	0.74389	0.90529
46	188,574	66,316	122,258	49,979	16,337	10,531	111,727	0.00330	0.74960	0.90717
47	168,832	47,910	120,922	34,589	13,321	9,904	111,018	0.00366	0.73765	0.91261
48	165,126	54,141	110,985	40,910	13,231	8,174	102,811	0.00403	0.73684	0.91833
49	157,941	55,255	102,686	41,175	14,080	8,048	94,638	0.00440	0.74705	0.92002
50	159,772	50,183	109,589	38,889	11,294	9,718	99,871	0.00478	0.75571	0.91193

Age	Population counts at age x			Population transitions age x to $x + 1$				Probability transitions age x to $x + 1$		
x	Population _{x} N_x	Inactive _{x} iN_x	Active _{x} aN_x	Inactive _{x} Inactive _{$x+1$} iN_x	Inactive _{x} Active _{$x+1$} iN_x^a	Active _{x} Inactive _{$x+1$} aN_x^i	Active _{x} Active _{$x+1$} aN_x^a	Living _{x} Dead _{$x+1$} p_x^d	Inactive _{x} Inactive _{$x+1$} ip_x^i	Active _{x} Active _{$x+1$} ap_x^a
51	144,763	42,898	101,865	33,483	9,415	9,759	92,106	0.00519	0.77348	0.90318
52	145,544	66,593	78,951	54,413	12,180	8,924	70,027	0.00563	0.79825	0.89163
53	113,324	36,043	77,281	29,631	6,412	9,843	67,438	0.00611	0.81386	0.87450
54	112,151	35,014	77,137	28,388	6,626	8,953	68,184	0.00664	0.81109	0.87245
55	97,591	37,883	59,708	32,057	5,826	7,985	51,723	0.00723	0.82318	0.86989
56	101,394	31,655	69,739	27,365	4,290	9,349	60,390	0.00790	0.84777	0.85924
57	87,934	48,035	39,899	42,045	5,990	6,194	33,705	0.00867	0.86346	0.85079
58	69,480	34,587	34,893	31,300	3,287	5,302	29,591	0.00953	0.87926	0.83823
59	80,420	38,815	41,605	35,324	3,491	5,418	36,187	0.01051	0.89812	0.85084
60	58,924	40,904	18,020	37,699	3,205	3,196	14,824	0.01158	0.90540	0.84563
61	77,609	51,303	26,306	47,048	4,255	4,601	21,705	0.01273	0.90739	0.81360
62	54,269	32,726	21,543	30,681	2,045	3,717	17,826	0.01395	0.91213	0.81462
63	62,960	47,918	15,042	45,867	2,051	2,828	12,214	0.01522	0.93477	0.80860
64	38,683	28,881	9,802	27,397	1,484	1,879	7,923	0.01652	0.93821	0.79715
65	67,745	62,888	4,857	59,657	3,231	931	3,926	0.01788	0.93167	0.79386

APPENDIX B2
Females with Grade 12 or more

Age x	Probability transitions age x to $x + 1$				Stationary population in each status			Person years lived in each status		
	Inactive _{x} Inactive _{$x+1$} $^i p^i_x$	Inactive _{x} Active _{$x+1$} $^i p^a_x$	Active _{x} Inactive _{$x+1$} $^a p^i_x$	Active _{x} Active _{$x+1$} $^a p^a_x$	Total I_x	Inactive $^i I_x$	Active $^a I_x$	Total L_x	Inactive $^i L_x$	Active $^a L_x$
20	0.63571	0.36367	0.51840	0.48098	98,461	56,755	41,705	98,430	57,227	41,203
21	0.71747	0.28188	0.46120	0.53815	98,400	57,700	40,700	98,368	58,934	39,433
22	0.80803	0.19130	0.36855	0.63078	98,336	60,169	38,167	98,303	61,426	36,876
23	0.84270	0.15660	0.34672	0.65259	98,270	62,684	35,585	98,236	63,923	34,312
24	0.81948	0.17981	0.32917	0.67012	98,202	65,163	33,039	98,167	64,719	33,448
25	0.79910	0.20017	0.27539	0.72388	98,132	64,275	33,857	98,096	62,480	35,616
26	0.78195	0.21730	0.25118	0.74807	98,060	60,686	37,374	98,023	58,763	39,260
27	0.76928	0.22994	0.23184	0.76738	97,986	56,841	41,145	97,949	55,054	42,895
28	0.75454	0.24466	0.20542	0.79378	97,911	53,266	44,645	97,871	51,314	46,557
29	0.74511	0.25406	0.18551	0.81366	97,832	49,362	48,470	97,792	47,567	50,225
30	0.73732	0.26182	0.17040	0.82874	97,751	45,772	51,979	97,709	44,189	53,520
31	0.73498	0.26413	0.16015	0.83895	97,667	42,606	55,061	97,624	41,369	56,254
32	0.73655	0.26251	0.15683	0.84223	97,580	40,133	57,447	97,534	39,351	58,183
33	0.73340	0.26561	0.15096	0.84804	97,488	38,569	58,919	97,440	37,875	59,565
34	0.73063	0.26832	0.14578	0.85317	97,391	37,181	60,210	97,340	36,562	60,778
35	0.73683	0.26204	0.14224	0.85663	97,289	35,943	61,346	97,234	35,576	61,658
36	0.74878	0.25001	0.13302	0.86576	97,179	35,210	61,969	97,120	34,909	62,211
37	0.75324	0.24544	0.12736	0.87132	97,061	34,608	62,453	96,997	34,315	62,682
38	0.76239	0.23617	0.12866	0.86990	96,933	34,022	62,911	96,864	34,027	62,836
39	0.76803	0.23040	0.12850	0.86994	96,794	34,033	62,762	96,719	34,118	62,601
40	0.75761	0.24066	0.12212	0.87616	96,643	34,203	62,440	96,559	33,870	62,689
41	0.75073	0.24736	0.11493	0.88317	96,476	33,537	62,939	96,384	32,974	63,410
42	0.75434	0.24354	0.10846	0.88943	96,292	32,411	63,881	96,191	31,894	64,296
43	0.75834	0.23930	0.10024	0.89740	96,089	31,377	64,711	95,975	30,830	65,146
44	0.74847	0.24889	0.09206	0.90529	95,862	30,282	65,580	95,735	29,492	66,243
45	0.74389	0.25315	0.09174	0.90529	95,608	28,702	66,906	95,466	28,096	67,370
46	0.74960	0.24709	0.08953	0.90717	95,325	27,490	67,835	95,167	27,085	68,083
47	0.73765	0.25869	0.08373	0.91261	95,010	26,679	68,330	94,836	26,040	68,796
48	0.73684	0.25913	0.07764	0.91833	94,662	25,401	69,261	94,472	24,748	69,724
49	0.74705	0.24855	0.07558	0.92002	94,281	24,094	70,187	94,074	23,699	70,374
50	0.75571	0.23950	0.08329	0.91193	93,866	23,304	70,562	93,642	23,396	70,245

Age x	Probability transitions age x to $x+1$				Stationary population in each status			Person years lived in each status		
	Inactive _{x} Inactive _{$x+1$} $i p^i_x$	Inactive _{x} Active _{$x+1$} $i p^a_x$	Active _{x} Inactive _{$x+1$} $a p^i_x$	Active _{x} Active _{$x+1$} $a p^a_x$	Total I_x	Inactive $i I_x$	Active $a I_x$	Total L_x	Inactive $i L_x$	Active $a L_x$
51	0.77348	0.22133	0.09163	0.90318	93,417	23,488	69,929	93,175	24,032	69,143
52	0.79825	0.19612	0.10275	0.89163	92,932	24,575	68,357	92,671	25,608	67,063
53	0.81386	0.18004	0.11939	0.87450	92,410	26,641	65,769	92,128	28,087	64,040
54	0.81109	0.18227	0.12092	0.87245	91,845	29,534	62,311	91,541	30,512	61,029
55	0.82318	0.16958	0.12288	0.86989	91,236	31,489	59,746	90,906	32,376	58,530
56	0.84777	0.14433	0.13286	0.85924	90,576	33,263	57,313	90,218	34,539	55,679
57	0.86346	0.12788	0.14055	0.85079	89,860	35,814	54,046	89,471	37,167	52,304
58	0.87926	0.11121	0.15224	0.83823	89,081	38,520	50,562	88,657	40,043	48,614
59	0.89812	0.09137	0.13866	0.85084	88,232	41,566	46,666	87,769	42,684	45,085
60	0.90540	0.08302	0.14280	0.84563	87,306	43,802	43,503	86,800	44,836	41,964
61	0.90739	0.07987	0.17367	0.81360	86,295	45,871	40,424	85,745	47,257	38,488
62	0.91213	0.07392	0.17143	0.81462	85,196	48,643	36,553	84,602	49,639	34,963
63	0.93477	0.05002	0.17618	0.80860	84,007	50,635	33,372	83,368	51,923	31,445
64	0.93821	0.04527	0.18633	0.79715	82,729	53,212	29,517	82,046	54,318	27,728
65	0.93167	0.05045	0.18826	0.79386	81,362	55,424	25,939	80,635	55,972	24,663

APPENDIX B3
Females with Grade 12 or more

Age		Various whole life expectancies			Present value of 1 to age 65		
x	Life expectancy	Inactive life expectancy	Active life expectancy	Mortality only basis	Active basis	Implied contingency deduction	
20	56.94	31.17	25.77	26.34	14.61	45%	
21	55.98	30.61	25.37	26.00	14.57	44%	
22	55.02	30.03	24.98	25.65	14.54	43%	
23	54.05	29.43	24.62	25.30	14.53	43%	
24	53.09	28.80	24.29	24.94	14.55	42%	
25	52.13	28.16	23.97	24.56	14.58	41%	
26	51.16	27.54	23.62	24.18	14.59	40%	
27	50.20	26.96	23.24	23.79	14.56	39%	
28	49.24	26.42	22.82	23.40	14.50	38%	
29	48.28	25.92	22.36	22.99	14.39	37%	
30	47.32	25.45	21.87	22.57	14.24	37%	
31	46.36	25.02	21.34	22.14	14.05	37%	
32	45.40	24.62	20.78	21.70	13.83	36%	
33	44.44	24.24	20.20	21.25	13.59	36%	
34	43.49	23.88	19.61	20.79	13.32	36%	
35	42.53	23.53	19.01	20.32	13.04	36%	
36	41.58	23.19	18.39	19.84	12.74	36%	
37	40.63	22.85	17.78	19.35	12.42	36%	
38	39.68	22.53	17.15	18.84	12.10	36%	
39	38.74	22.21	16.53	18.33	11.76	36%	
40	37.80	21.89	15.91	17.80	11.42	36%	
41	36.86	21.58	15.28	17.27	11.06	36%	
42	35.93	21.28	14.65	16.72	10.69	36%	
43	35.01	20.99	14.02	16.16	10.31	36%	
44	34.09	20.72	13.37	15.59	9.90	36%	
45	33.18	20.47	12.71	15.01	9.48	37%	
46	32.28	20.23	12.04	14.41	9.03	37%	
47	31.38	20.01	11.37	13.81	8.56	38%	
48	30.49	19.81	10.68	13.19	8.07	39%	
49	29.62	19.63	9.99	12.56	7.55	40%	
50	28.74	19.46	9.28	11.92	7.02	41%	

Age	Various whole life expectancies			Present value of 1 to age 65		
x	Life expectancy	Inactive life expectancy	Active life expectancy	Mortality only basis	Active basis	Implied contingency deduction
51	27.88	19.31	8.57	11.26	6.47	43%
52	27.02	19.15	7.87	10.58	5.91	44%
53	26.17	18.98	7.19	9.90	5.36	46%
54	25.33	18.79	6.54	9.19	4.82	48%
55	24.50	18.58	5.91	8.47	4.29	49%
56	23.67	18.36	5.31	7.72	3.78	51%
57	22.86	18.12	4.73	6.96	3.28	53%
58	22.05	17.86	4.19	6.18	2.79	55%
59	21.26	17.58	3.68	5.38	2.33	57%
60	20.48	17.28	3.20	4.56	1.89	58%

APPENDIX C1
Males with less than Grade 12

Age x	Population counts at age x			Population transitions age x to $x + 1$				Probability transitions age x to $x + 1$		
	Population _{x} N_x	Inactive _{x} iN_x	Active _{x} aN_x	Inactive _{$x+1$} iN_{x+1}	Inactive _{$x+1$} iN_{x+1}^a	Active _{$x+1$} aN_{x+1}	Active _{$x+1$} aN_{x+1}^a	Living _{$x+1$} p_x^d	Inactive _{$x+1$} $i p_x^i$	Active _{$x+1$} $a p_x^a$
20	242,136	223,435	18,701	198,713	24,722	9,422	9,279	0.00365	0.87420	0.46248
21	248,476	191,221	57,255	163,149	28,072	29,701	27,554	0.00405	0.86915	0.48297
22	244,524	199,573	44,951	162,039	37,534	19,880	25,071	0.00440	0.82846	0.51263
23	221,991	169,364	52,627	132,691	36,673	23,411	29,216	0.00472	0.79510	0.55372
24	248,098	167,693	80,405	127,159	40,534	32,295	48,110	0.00498	0.76710	0.57836
25	252,023	162,825	89,198	118,556	44,269	32,646	56,552	0.00520	0.73956	0.61389
26	243,310	158,484	84,826	111,426	47,058	28,209	56,617	0.00536	0.71193	0.64683
27	234,893	146,548	88,345	101,285	45,263	28,436	59,909	0.00547	0.69352	0.66921
28	230,938	120,835	110,103	80,919	39,916	32,320	77,783	0.00558	0.67763	0.68997
29	252,779	148,161	104,618	99,598	48,563	29,260	75,358	0.00563	0.66730	0.70920
30	257,119	138,733	118,386	91,982	46,751	30,614	87,772	0.00567	0.66399	0.72737
31	271,141	166,166	104,975	112,435	53,731	26,122	78,853	0.00573	0.66660	0.74172
32	293,128	169,458	123,670	115,590	53,868	27,963	95,707	0.00584	0.67544	0.75900
33	273,158	154,748	118,410	105,703	49,045	25,559	92,851	0.00602	0.67846	0.77422
34	249,765	141,619	108,146	95,740	45,879	22,901	85,245	0.00630	0.67543	0.78116
35	209,258	104,496	104,762	70,065	34,431	21,474	83,288	0.00665	0.66921	0.78631
36	246,823	126,559	120,264	86,227	40,332	23,257	97,007	0.00707	0.67165	0.79555
37	234,688	111,692	122,996	77,601	34,091	23,496	99,500	0.00753	0.68245	0.80173
38	263,290	124,715	138,575	85,090	39,625	27,365	111,210	0.00800	0.68268	0.79911
39	208,381	101,164	107,217	70,414	30,750	21,089	86,128	0.00848	0.68260	0.79606
40	207,704	106,514	101,190	72,327	34,187	20,944	80,246	0.00898	0.68115	0.79115
41	225,069	102,462	122,607	70,080	32,382	27,795	94,812	0.00951	0.67497	0.77478
42	246,246	122,250	123,996	85,853	36,397	28,311	95,685	0.01011	0.68691	0.76468
43	169,813	80,198	89,615	56,754	23,444	20,766	68,849	0.01079	0.69681	0.76195
44	176,196	77,879	98,317	55,491	22,388	22,739	75,578	0.01156	0.70185	0.75963
45	198,422	85,011	113,411	59,743	25,268	25,119	88,292	0.01243	0.69864	0.76435
46	193,675	82,411	111,264	58,899	23,512	26,269	84,995	0.01340	0.69915	0.76095
47	196,309	83,492	112,817	61,099	22,393	25,976	86,841	0.01446	0.71285	0.75576
48	170,171	80,461	89,710	60,273	20,188	21,347	68,363	0.01561	0.72873	0.75437
49	192,778	87,953	104,825	67,623	20,330	23,180	81,645	0.01686	0.74662	0.75811
50	148,962	65,971	82,991	49,946	16,025	16,556	66,435	0.01819	0.74992	0.77409

Age	Population counts at age x			Population transitions age x to $x+1$				Probability transitions age x to $x+1$		
x	Population _{x} N_x	Inactive _{x} iN_x	Active _{x} aN_x	Inactive _{x} Inactive _{$x+1$} iN_x	Inactive _{x} Active _{$x+1$} iN_x^a	Active _{x} Inactive _{$x+1$} aN_x^i	Active _{x} Active _{$x+1$} aN_x^a	Living _{x} Dead _{$x+1$} p_x^d	Inactive _{x} Inactive _{$x+1$} $i p_x^i$	Active _{x} Active _{$x+1$} $a p_x^a$
51	138,087	75,334	62,753	56,155	19,179	11,757	50,996	0.01959	0.73615	0.78995
52	152,513	72,201	80,312	54,158	18,043	15,592	64,720	0.02107	0.73195	0.79179
53	158,244	83,646	74,598	64,643	19,003	14,852	59,746	0.02262	0.74505	0.78530
54	112,274	49,159	63,115	37,663	11,496	12,777	50,338	0.02423	0.75169	0.78001
55	128,418	67,124	61,294	51,833	15,291	11,891	49,403	0.02590	0.74971	0.78095
56	107,672	64,898	42,774	51,523	13,375	9,320	33,454	0.02766	0.76121	0.77416
57	138,838	75,395	63,443	59,444	15,951	12,822	50,621	0.02952	0.76762	0.76818
58	118,771	62,737	56,034	51,074	11,663	13,512	42,522	0.03148	0.77491	0.75504
59	130,738	76,274	54,464	63,312	12,962	13,109	41,355	0.03356	0.79524	0.73360
60	101,642	72,771	28,871	61,648	11,123	8,394	20,477	0.03577	0.80842	0.71543
61	117,584	94,302	23,282	81,636	12,666	6,683	16,599	0.03810	0.82494	0.68382
62	115,987	92,360	23,627	80,071	12,289	7,003	16,624	0.04057	0.83116	0.67951
63	111,502	97,864	13,638	88,016	9,848	4,242	9,396	0.04319	0.84547	0.66810
64	115,129	103,730	11,399	94,225	9,505	3,620	7,779	0.04595	0.86246	0.65448
65	119,874	106,360	13,514	96,614	9,746	4,291	9,223	0.04886	0.86398	0.64911

APPENDIX C2
Males with less than Grade 12

Age x	Probability transitions age x to $x + 1$				Stationary population in each status			Person years lived in each status		
	Inactive _{x} Inactive _{$x+1$} ${}^ip'_x$	Inactive _{x} Active _{$x+1$} ${}^ip^a_x$	Active _{x} Inactive _{$x+1$} ${}^ap'_x$	Active _{x} Active _{$x+1$} ${}^ap^a_x$	Total I_x	Inactive i'_x	Active a'_x	Total L_x	Inactive iL_x	Active aL_x
20	0.87420	0.12215	0.53387	0.46248	91,404	78,830	12,574	91,238	77,228	14,009
21	0.86915	0.12680	0.51299	0.48297	91,071	75,626	15,445	90,887	74,640	16,247
22	0.82846	0.16714	0.48297	0.51263	90,702	73,653	17,049	90,503	71,453	19,050
23	0.79510	0.20019	0.44156	0.55372	90,303	69,253	21,050	90,090	66,805	23,285
24	0.76710	0.22792	0.41666	0.57836	89,877	64,357	25,519	89,653	62,179	27,474
25	0.73956	0.25524	0.38091	0.61389	89,429	60,001	29,428	89,197	57,793	31,404
26	0.71193	0.28271	0.34782	0.64683	88,965	55,584	33,380	88,726	53,383	35,343
27	0.69352	0.30100	0.32532	0.66921	88,488	51,182	37,306	88,246	49,407	38,839
28	0.67763	0.31679	0.30445	0.68997	88,004	47,632	40,371	87,758	46,100	41,658
29	0.66730	0.32707	0.28518	0.70920	87,513	44,568	42,945	87,267	43,278	43,989
30	0.66399	0.33034	0.26696	0.72737	87,021	41,987	45,033	86,774	40,944	45,830
31	0.66660	0.32767	0.25255	0.74172	86,528	39,901	46,626	86,280	39,138	47,142
32	0.67544	0.31872	0.23517	0.75900	86,032	38,374	47,658	85,781	37,751	48,030
33	0.67846	0.31552	0.21976	0.77422	85,530	37,127	48,403	85,272	36,477	48,796
34	0.67543	0.31828	0.21255	0.78116	85,015	35,826	49,189	84,748	35,240	49,508
35	0.66921	0.32414	0.20703	0.78631	84,480	34,653	49,827	84,199	34,080	50,119
36	0.67165	0.32128	0.19738	0.79555	83,918	33,506	50,412	83,621	32,980	50,641
37	0.68245	0.31002	0.19075	0.80173	83,325	32,454	50,870	83,011	32,153	50,858
38	0.68268	0.30932	0.19289	0.79911	82,698	31,852	50,846	82,367	31,702	50,665
39	0.68260	0.30892	0.19546	0.79606	82,036	31,552	50,484	81,688	31,479	50,210
40	0.68115	0.30988	0.19988	0.79115	81,341	31,405	49,935	80,975	31,389	49,587
41	0.67497	0.31552	0.21571	0.77478	80,610	31,372	49,238	80,227	31,584	48,642
42	0.68691	0.30298	0.22521	0.76468	79,844	31,797	48,047	79,440	32,229	47,211
43	0.69681	0.29240	0.22727	0.76195	79,036	32,662	46,374	78,610	32,980	45,630
44	0.70185	0.28659	0.22882	0.75963	78,184	33,299	44,885	77,732	33,470	44,262
45	0.69864	0.28893	0.22323	0.76435	77,280	33,641	43,639	76,800	33,443	43,357
46	0.69915	0.28746	0.22566	0.76095	76,320	33,245	43,075	75,809	33,104	42,705
47	0.71285	0.27270	0.22978	0.75576	75,298	32,963	42,334	74,753	33,094	41,659
48	0.72873	0.25566	0.23002	0.75437	74,209	33,226	40,984	73,630	33,432	40,197
49	0.74662	0.23653	0.22503	0.75811	73,051	33,639	39,411	72,435	33,812	38,623
50	0.74992	0.23189	0.20772	0.77409	71,819	33,985	37,835	71,166	33,665	37,501

Age x	Probability transitions age x to $x+1$				Stationary population in each status			Person years lived in each status		
	Inactive _{x} Inactive _{$x+1$} ${}^i p_x^i$	Inactive _{x} Active _{$x+1$} ${}^i p_x^a$	Active _{x} Inactive _{$x+1$} ${}^a p_x^i$	Active _{x} Active _{$x+1$} ${}^a p_x^a$	Total I_x	Inactive iI_x	Active aI_x	Total L_x	Inactive iL_x	Active aL_x
51	0.73615	0.24425	0.19046	0.78995	70,513	33,345	37,168	69,822	32,485	37,337
52	0.73195	0.24698	0.18713	0.79179	69,131	31,626	37,506	68,403	30,896	37,506
53	0.74505	0.23233	0.19208	0.78530	67,674	30,167	37,507	66,909	29,924	36,985
54	0.75169	0.22408	0.19577	0.78001	66,144	29,680	36,463	65,343	29,565	35,778
55	0.74971	0.22439	0.19315	0.78095	64,541	29,449	35,093	63,706	29,152	34,553
56	0.76121	0.21112	0.19818	0.77416	62,870	28,856	34,014	62,000	28,781	33,219
57	0.76762	0.20286	0.20230	0.76818	61,130	28,706	32,424	60,228	28,651	31,577
58	0.77491	0.19361	0.21348	0.75504	59,326	28,595	30,731	58,392	28,657	29,735
59	0.79524	0.17120	0.23284	0.73360	57,458	28,719	28,740	56,494	29,124	27,370
60	0.80842	0.15581	0.24881	0.71543	55,530	29,530	26,000	54,537	29,936	24,601
61	0.82494	0.13696	0.27808	0.68382	53,544	30,342	23,202	52,524	30,912	21,612
62	0.83116	0.12826	0.27992	0.67951	51,504	31,482	20,022	50,459	31,627	18,832
63	0.84547	0.11134	0.28872	0.66810	49,414	31,771	17,643	48,347	31,863	16,484
64	0.86246	0.09159	0.29957	0.65448	47,280	31,955	15,325	46,194	32,053	14,141
65	0.86398	0.08716	0.30203	0.64911	45,108	32,151	12,957	44,006	31,921	12,085

APPENDIX C3
Males with less than Grade 12

Age		Various whole life expectancies			Present value of 1 to age 65	
x	Life expectancy	Inactive life expectancy	Active life expectancy	Mortality only basis	Active basis	Implied contingency deduction
20	43.02	24.30	18.72	23.59	11.34	52%
21	42.18	23.54	18.64	23.26	11.32	51%
22	41.35	22.81	18.53	22.92	11.40	50%
23	40.53	22.12	18.40	22.58	11.50	49%
24	39.72	21.48	18.23	22.24	11.57	48%
25	38.91	20.90	18.02	21.90	11.61	47%
26	38.11	20.36	17.76	21.55	11.60	46%
27	37.32	19.86	17.45	21.19	11.55	45%
28	36.52	19.41	17.11	20.82	11.46	45%
29	35.72	18.99	16.73	20.45	11.33	45%
30	34.92	18.60	16.32	20.06	11.17	44%
31	34.12	18.24	15.88	19.67	10.97	44%
32	33.31	17.89	15.42	19.26	10.76	44%
33	32.50	17.55	14.95	18.84	10.52	44%
34	31.70	17.23	14.47	18.41	10.27	44%
35	30.89	16.92	13.98	17.98	10.00	44%
36	30.10	16.63	13.47	17.54	9.72	45%
37	29.31	16.35	12.96	17.09	9.41	45%
38	28.53	16.08	12.44	16.63	9.10	45%
39	27.75	15.83	11.93	16.17	8.78	46%
40	26.99	15.57	11.41	15.69	8.45	46%
41	26.23	15.33	10.90	15.22	8.11	47%
42	25.47	15.08	10.39	14.73	7.78	47%
43	24.73	14.82	9.90	14.23	7.45	48%
44	23.99	14.56	9.43	13.73	7.13	48%
45	23.27	14.30	8.97	13.22	6.81	48%
46	22.55	14.04	8.51	12.70	6.50	49%
47	21.85	13.79	8.06	12.18	6.18	49%
48	21.17	13.55	7.62	11.64	5.85	50%
49	20.49	13.31	7.19	11.10	5.54	50%
50	19.84	13.06	6.77	10.55	5.23	50%

Age	Various whole life expectancies			Present value of 1 to age 65		
x	Life expectancy	Inactive life expectancy	Active life expectancy	Mortality only basis	Active basis	Implied contingency deduction
51	19.19	12.83	6.36	10.00	4.92	51%
52	18.57	12.62	5.95	9.43	4.60	51%
53	17.96	12.43	5.53	8.85	4.25	52%
54	17.36	12.27	5.09	8.26	3.89	53%
55	16.78	12.11	4.67	7.65	3.53	54%
56	16.21	11.97	4.24	7.02	3.16	55%
57	15.66	11.84	3.82	6.37	2.78	56%
58	15.12	11.72	3.40	5.70	2.40	58%
59	14.60	11.60	3.00	5.01	2.01	60%
60	14.09	11.48	2.61	4.28	1.63	62%

APPENDIX D1
Males with Grade 12 or more

Age x	Population counts at age x			Population transitions age x to $x + 1$				Probability transitions age x to $x + 1$		
	Population _{x} N_x	Inactive _{x} iN_x	Active _{x} aN_x	Inactive _{x} iN_x	Inactive _{$x+1$} iN_{x+1}	Active _{x} aN_x	Active _{$x+1$} aN_{x+1}	Living _{x} p^d_x	Inactive _{x} p^i_x	Active _{x} p^a_x
20	259,489	228,250	31,239	139,402	88,848	14,678	16,561	0.00204	0.58167	0.50411
21	274,858	218,206	56,652	149,256	68,950	21,855	34,797	0.00220	0.64513	0.58306
22	284,702	233,419	51,283	175,800	57,619	15,198	36,085	0.00231	0.71809	0.65520
23	271,738	201,440	70,298	148,385	53,055	19,983	50,315	0.00237	0.74373	0.70895
24	285,706	167,711	117,995	117,317	50,394	31,545	86,450	0.00238	0.71805	0.72461
25	325,679	200,054	125,625	135,310	64,744	29,756	95,869	0.00236	0.68530	0.74661
26	275,503	152,002	123,501	101,140	50,862	25,315	98,186	0.00231	0.67007	0.77714
27	312,686	156,408	156,278	100,215	56,193	29,282	126,996	0.00226	0.65141	0.80304
28	289,837	149,322	140,515	91,106	58,216	22,784	117,731	0.00218	0.62442	0.82277
29	277,370	128,016	149,354	77,566	50,450	23,941	125,413	0.00215	0.60687	0.83700
30	255,484	137,192	118,292	81,611	55,581	16,432	101,860	0.00216	0.59890	0.84732
31	302,422	137,638	164,784	83,261	54,377	21,592	143,192	0.00219	0.59859	0.86378
32	239,169	101,735	137,434	60,163	41,572	15,642	121,792	0.00224	0.59782	0.87483
33	242,351	79,196	163,155	46,004	33,192	17,530	145,625	0.00232	0.58542	0.88758
34	237,625	81,313	156,312	49,753	31,560	15,146	141,166	0.00240	0.59515	0.89556
35	229,861	78,663	151,198	48,643	30,020	13,944	137,254	0.00250	0.61353	0.90314
36	259,967	97,417	162,550	62,400	35,017	16,718	145,832	0.00263	0.62899	0.89990
37	270,203	80,096	190,107	52,611	27,485	18,676	171,431	0.00278	0.64611	0.89714
38	195,302	80,464	114,838	52,397	28,067	10,081	104,757	0.00295	0.65208	0.90303
39	259,161	77,475	181,686	49,241	28,234	15,647	166,039	0.00316	0.64149	0.91035
40	200,737	50,859	149,878	31,675	19,184	11,632	138,246	0.00340	0.62837	0.91461
41	230,996	59,773	171,223	39,122	20,651	12,711	158,512	0.00367	0.63758	0.92080
42	241,503	57,475	184,028	38,554	18,921	13,080	170,948	0.00398	0.65985	0.92371
43	202,027	44,639	157,388	28,218	16,421	12,127	145,261	0.00433	0.65106	0.92215
44	184,212	40,406	143,806	26,710	13,696	11,209	132,597	0.00473	0.64282	0.91816
45	186,815	50,101	136,714	32,647	17,454	8,022	128,692	0.00518	0.65244	0.92662
46	185,647	55,078	130,569	35,009	20,069	7,444	123,125	0.00568	0.63959	0.93679
47	170,242	46,553	123,689	31,102	15,451	6,316	117,373	0.00625	0.64643	0.93997
48	166,333	31,197	135,136	22,854	8,343	7,553	127,583	0.00689	0.68918	0.93990
49	113,240	18,526	94,714	13,238	5,288	5,029	89,685	0.00761	0.72033	0.93807
50	132,776	31,866	100,910	22,613	9,253	5,696	95,214	0.00841	0.70545	0.93722

Age	Population counts at age x			Population transitions age x to $x+1$				Probability transitions age x to $x+1$		
x	Population _{x} N_x	Inactive _{x} iN_x	Active _{x} aN_x	Inactive _{x} Inactive _{$x+1$} iN_x^i	Inactive _{x} Active _{$x+1$} iN_x^a	Active _{x} Inactive _{$x+1$} aN_x^i	Active _{x} Active _{$x+1$} aN_x^a	Living _{x} Dead _{$x+1$} p_x^d	Inactive _{x} Inactive _{$x+1$} ip_x^i	Active _{x} Active _{$x+1$} ap_x^a
51	135,238	42,007	93,231	30,809	11,198	6,088	87,143	0.00931	0.71643	0.93056
52	135,077	25,502	109,575	19,660	5,842	6,854	102,721	0.01031	0.73989	0.92653
53	133,982	38,346	95,636	28,818	9,528	5,736	89,900	0.01141	0.75062	0.92793
54	106,039	22,608	83,431	17,537	5,071	5,992	77,439	0.01263	0.75089	0.92270
55	107,923	23,975	83,948	19,464	4,511	5,430	78,518	0.01397	0.78321	0.91875
56	78,741	17,530	61,211	14,363	3,167	4,960	56,251	0.01542	0.80243	0.91411
57	102,575	28,642	73,933	23,467	5,175	7,526	66,407	0.01699	0.80541	0.89219
58	70,367	24,513	45,854	21,231	3,282	5,904	39,950	0.01868	0.82520	0.87130
59	66,455	25,745	40,710	22,700	3,045	6,313	34,397	0.02051	0.85619	0.84126
60	51,369	34,454	16,915	30,566	3,888	2,659	14,256	0.02246	0.86496	0.82534
61	59,205	33,425	25,780	29,723	3,702	4,377	21,403	0.02455	0.86638	0.81469
62	56,861	28,551	28,310	25,952	2,599	5,237	23,073	0.02680	0.87426	0.80021
63	58,029	31,218	26,811	28,620	2,598	5,156	21,655	0.02920	0.88639	0.78776
64	55,204	40,100	15,104	37,423	2,677	3,395	11,709	0.03176	0.89662	0.77071
65	50,569	38,081	12,488	35,539	2,542	2,807	9,681	0.03449	0.90106	0.74846

APPENDIX D2
Males with Grade 12 or more

Age x	Probability transitions age x to x + 1				Stationary population in each status			Person years lived in each status		
	Inactive _x Inactive _{x+1} <i>i</i> <i>p</i> _x ⁱ	Inactive _x Active _{x+1} <i>i</i> <i>p</i> _x ^a	Active _x Inactive _{x+1} <i>a</i> <i>p</i> _x ⁱ	Active _x Active _{x+1} <i>a</i> <i>p</i> _x ^a	Total <i>L</i> _x	Inactive <i>i</i> <i>L</i> _x	Active <i>a</i> <i>L</i> _x	Total <i>L</i> _x	Inactive <i>i</i> <i>L</i> _x	Active <i>a</i> <i>L</i> _x
20	0.58167	0.41629	0.49385	0.50411	97,503	51,351	46,152	97,404	52,006	45,397
21	0.64513	0.35267	0.41475	0.58306	97,304	52,662	44,643	97,197	52,575	44,622
22	0.71809	0.27960	0.34249	0.65520	97,090	52,489	44,601	96,978	52,728	44,250
23	0.74373	0.25390	0.28868	0.70895	96,866	52,967	43,899	96,751	52,517	44,235
24	0.71805	0.27957	0.27301	0.72461	96,636	52,066	44,570	96,521	50,810	45,711
25	0.68530	0.31234	0.25103	0.74661	96,406	49,554	46,852	96,292	47,637	48,655
26	0.67007	0.32761	0.22055	0.77714	96,178	45,721	50,458	96,067	43,743	52,325
27	0.65141	0.34633	0.19470	0.80304	95,956	41,765	54,191	95,848	39,761	56,087
28	0.62442	0.37340	0.17505	0.82277	95,739	37,757	57,982	95,635	35,741	59,894
29	0.60687	0.39098	0.16085	0.83700	95,531	33,726	61,805	95,428	32,067	63,361
30	0.59890	0.39894	0.15052	0.84732	95,325	30,409	64,917	95,222	29,196	66,027
31	0.59859	0.39922	0.13403	0.86378	95,119	27,983	67,136	95,015	26,866	68,149
32	0.59782	0.39993	0.12293	0.87483	94,911	25,749	69,162	94,805	24,822	69,983
33	0.58542	0.41226	0.11010	0.88758	94,698	23,895	70,803	94,589	22,840	71,749
34	0.59515	0.40245	0.10204	0.89556	94,479	21,784	72,695	94,366	21,084	73,282
35	0.61353	0.38397	0.09436	0.90314	94,252	20,383	73,870	94,134	19,929	74,205
36	0.62899	0.36839	0.09747	0.89990	94,016	19,476	74,541	93,893	19,496	74,397
37	0.64611	0.35112	0.10009	0.89714	93,769	19,515	74,254	93,639	19,778	73,861
38	0.65208	0.34497	0.09402	0.90303	93,509	20,041	73,468	93,371	20,008	73,363
39	0.64149	0.35535	0.08649	0.91035	93,233	19,976	73,257	93,086	19,563	73,523
40	0.62837	0.36824	0.08199	0.91461	92,939	19,150	73,788	92,781	18,617	74,164
41	0.63758	0.35875	0.07553	0.92080	92,623	18,084	74,539	92,453	17,622	74,831
42	0.65985	0.33617	0.07231	0.92371	92,283	17,160	75,123	92,100	16,958	75,142
43	0.65106	0.34460	0.07351	0.92215	91,916	16,755	75,161	91,717	16,595	75,122
44	0.64282	0.35245	0.07711	0.91816	91,518	16,434	75,084	91,301	16,394	74,907
45	0.65244	0.34239	0.06820	0.92662	91,085	16,354	74,731	90,849	16,060	74,789
46	0.63959	0.35473	0.05753	0.93679	90,613	15,767	74,847	90,356	15,079	75,277
47	0.64643	0.34732	0.05378	0.93997	90,099	14,390	75,708	89,817	13,882	75,935
48	0.68918	0.30393	0.05322	0.93990	89,536	13,374	76,162	89,227	13,322	75,905
49	0.72033	0.27206	0.05433	0.93807	88,919	13,270	75,649	88,581	13,469	75,112
50	0.70545	0.28614	0.05437	0.93722	88,243	13,669	74,574	87,872	13,683	74,189

Age	Probability transitions age x to $x+1$				Stationary population in each status			Person years lived in each status		
x	Inactive _{x} Inactive _{$x+1$} ${}^i p_x^i$	Inactive _{x} Active _{$x+1$} ${}^i p_x^a$	Active _{x} Inactive _{$x+1$} ${}^a p_x^i$	Active _{x} Active _{$x+1$} ${}^a p_x^a$	Total I_x	Inactive iI_x	Active aI_x	Total L_x	Inactive iL_x	Active aL_x
51	0.71643	0.27426	0.06013	0.93056	87,501	13,697	73,804	87,093	13,974	73,119
52	0.73989	0.24980	0.06316	0.92653	86,686	14,251	72,435	86,239	14,685	71,554
53	0.75062	0.23797	0.06065	0.92793	85,792	15,119	70,673	85,303	15,377	69,926
54	0.75089	0.23647	0.06467	0.92270	84,813	15,635	69,178	84,277	15,924	68,353
55	0.78321	0.20283	0.06729	0.91875	83,742	16,214	67,528	83,157	16,728	66,429
56	0.80243	0.18215	0.07048	0.91411	82,572	17,243	65,330	81,936	17,841	64,094
57	0.80541	0.17760	0.09082	0.89219	81,299	18,440	62,859	80,609	19,501	61,108
58	0.82520	0.15612	0.11002	0.87130	79,918	20,561	59,357	79,171	22,029	57,142
59	0.85619	0.12330	0.13823	0.84126	78,425	23,497	54,928	77,621	25,604	52,017
60	0.86496	0.11258	0.15220	0.82534	76,817	27,711	49,106	75,954	29,577	46,377
61	0.86638	0.10907	0.16076	0.81469	75,091	31,443	43,649	74,170	32,851	41,319
62	0.87426	0.09894	0.17299	0.80021	73,248	34,258	38,989	72,266	35,477	36,789
63	0.88639	0.08441	0.18304	0.78776	71,285	36,696	34,589	70,244	37,777	32,467
64	0.89662	0.07162	0.19753	0.77071	69,203	38,858	30,346	68,104	39,846	28,258
65	0.90106	0.06445	0.21705	0.74846	67,005	40,835	26,170	65,850	41,655	24,195

APPENDIX D3
Males with Grade 12 or more

Age	Various whole life expectancies			Present value of 1 to age 65		
x	Life expectancy	Inactive life expectancy	Active life expectancy	Mortality only basis	Active basis	Implied contingency deduction
20	49.95	20.09	29.86	25.43	17.32	32%
21	49.05	19.59	29.46	25.10	17.34	31%
22	48.16	19.09	29.06	24.77	17.34	30%
23	47.27	18.59	28.67	24.44	17.36	29%
24	46.38	18.10	28.28	24.09	17.37	28%
25	45.49	17.61	27.88	23.74	17.37	27%
26	44.59	17.16	27.44	23.38	17.33	26%
27	43.70	16.74	26.95	23.00	17.25	25%
28	42.79	16.36	26.43	22.62	17.13	24%
29	41.89	16.03	25.86	22.22	16.97	24%
30	40.97	15.72	25.25	21.81	16.75	23%
31	40.06	15.45	24.61	21.39	16.51	23%
32	39.15	15.20	23.95	20.96	16.23	23%
33	38.24	14.97	23.26	20.52	15.93	22%
34	37.32	14.77	22.56	20.07	15.59	22%
35	36.41	14.58	21.83	19.61	15.23	22%
36	35.50	14.40	21.10	19.13	14.85	22%
37	34.59	14.23	20.36	18.65	14.46	22%
38	33.69	14.06	19.63	18.15	14.07	23%
39	32.79	13.89	18.90	17.65	13.66	23%
40	31.89	13.72	18.17	17.13	13.25	23%
41	31.00	13.57	17.43	16.61	12.82	23%
42	30.11	13.43	16.68	16.07	12.36	23%
43	29.23	13.30	15.93	15.52	11.90	23%
44	28.35	13.17	15.18	14.97	11.41	24%
45	27.48	13.05	14.43	14.40	10.92	24%
46	26.63	12.95	13.68	13.82	10.42	25%
47	25.77	12.85	12.92	13.23	9.89	25%
48	24.93	12.78	12.16	12.63	9.35	26%
49	24.10	12.72	11.39	12.02	8.78	27%
50	23.28	12.66	10.62	11.40	8.21	28%

Age		Various whole life expectancies			Present value of 1 to age 65	
x	Life expectancy	Inactive life expectancy	Active life expectancy	Mortality only basis	Active basis	Implied contingency deduction
51	22.48	12.61	9.86	10.77	7.63	29%
52	21.68	12.57	9.11	10.12	7.04	30%
53	20.90	12.53	8.37	9.47	6.44	32%
54	20.14	12.49	7.65	8.80	5.85	34%
55	19.39	12.46	6.93	8.11	5.24	35%
56	18.66	12.44	6.22	7.41	4.63	37%
57	17.94	12.41	5.53	6.70	4.03	40%
58	17.24	12.38	4.86	5.96	3.42	43%
59	16.56	12.34	4.23	5.21	2.84	45%
60	15.90	12.26	3.64	4.42	2.28	48%

Cumulative index

- Abraham SE, Malherbe KL & Carswell MJB (2018). Extending the normal retirement age in occupational defined-contribution funds in South Africa. *SAAJ* **18**, 41–70.
DOI: <http://dx.doi.org/10.4314/saaj.v18i1.3>
- Adékambi F (2015). Reserves in the multi-state health insurance model with stochastic interest of diffusion type. *SAAJ* **15**, 109–29. DOI: <http://dx.doi.org/10.4314/saaj.v15i1.5>
- Adékambi F (2018). Linear predictor of the discounted renewal aggregate claims with dependent inter-occurrence times. *SAAJ* **18**, 17–39. DOI: <http://dx.doi.org/10.4314/saaj.v18i1.2>
- Agostinho PJF & Cherry CJ (2016). The significance of claims fraud in microinsurance and a statistical method to channel limited fraud identification resources. *SAAJ* **16**, 143–81.
DOI: <http://dx.doi.org/10.4314/saaj.v16i1.6>
- Andrew JP (2004). The conversion of members' rights in South African retirement funds from defined benefits to defined contributions and the statutory apportionment of the resulting actuarial surplus. *SAAJ* **4**, 1–62
- Asher A (2001). The appropriate disposal of retirement fund surpluses. *SAAJ* **1**, 1–33
- Asher A (2002). What actuaries might learn about life. *SAAJ* **2**, 53–68
- Asher A (2005). The relative investment performance of the Community Growth Fund. *SAAJ* **5**, 1–26
- Asher A (2007). Pension benefit design: flexibility and the integration of insurance over the life cycle. *SAAJ* **7**, 73–115
- Bertolis DE & Hayes M (2014). An investigation into South African general equity unit trust performance during different economic periods. *SAAJ* **14**, 73–99. DOI: <http://dx.doi.org/10.4314/saaj.v14i1.3>
- Butler MJB, Hu B & Kloppers D (2013). A comparison of probability of ruin and expected discounted utility as objective functions for choosing a post-retirement investment strategy. *SAAJ* **13**, 185–219. DOI: <http://dx.doi.org/10.4314/saaj.v13i1.6>
- Butler MJB, Reddy T & Da Silva R (2015). The process of ethical decision-making in South African retirement funds. *SAAJ* **15**, 171–208. DOI: <http://dx.doi.org/10.4314/saaj.v15i1.7>
- Butler MJB & Van Zyl CJ (2012). Consumption changes on retirement for South African households. *SAAJ* **12**, 1–29. DOI: <http://dx.doi.org/10.4314/saaj.v12i1.1>
- Butler MJB & Van Zyl CJ (2012). Retirement adequacy goals for South African households. *SAAJ* **12**, 31–64. DOI: <http://dx.doi.org/10.4314/saaj.v12i1.2>
- Caldis KS, McLeod HD & Smith PR (2001). The fall of the bamboo curtain: a review of complementary medicine in South Africa. *SAAJ* **1**, 63–93

- Carswell MBJ, Ng D, Eydatoula Z, Murray SH & Curtis M (2019). The effectiveness of South African defined-contribution occupational fund benefit statements to inform and persuade: framework and initial applications. *SAAJ* **19**, 1–25. DOI: <http://dx.doi.org/10.4314/saaj.v19i1.1>
- Channa A, Yuan J & Carswell MBJ (2021). Updated remarriage contingency deductions for widowed South Africans. *SAAJ* **21**, 49–73. DOI: <https://dx.doi.org/10.4314/saaj.v21i1.3>
- Clover RJ (2008). Taxation of life insurance in South Africa revisited. *SAAJ* **8**, 1–34
- Clur JC, Dorrington RE, Schriek KA & Lewis PL (2013). Modelling the mortality of members of group schemes in South Africa. *SAAJ* **13**, 143–83. DOI: <http://dx.doi.org/10.4314/saaj.v13i1.5>
- Dardis A (2002). Risk-position reporting in the South African life-insurance industry. *SAAJ* **2**, 1–28
- Da Silva R, Milner K, Kolbe-Alexander TL, Greyling M & Patel D (2014). The prevalence of chronic conditions associated with modifiable health risk factors in corporate employees in South Africa. *SAAJ* **14**, 101–36. DOI: <http://dx.doi.org/10.4314/saaj.v14i1.4>
- Da Silva R & Wayburne L (2008). The effects of HIV/AIDS on medical schemes in South Africa. *SAAJ* **8**, 35–91
- Davies N & Kijko A (2003). Seismic risk assessment: with an application to the South African insurance industry. *SAAJ* **3**, 1–28
- Davis RWD & Kendal S (2012). Surplus? What surplus? Did the Pension Funds Second Amendment Act achieve its aims? *SAAJ* **12**, 97–128. DOI: <http://dx.doi.org/10.4314/saaj.v12i1.4>
- Dorrington RE & Tootla S (2007). South African annuitant standard mortality tables 1996–2000 (SAIML98 and SAIFL98). *SAAJ* **7**, 161–84
- Emslie S & Mataramvura S (2020). Comparison of numerical methods to price zero coupon bonds in a two-factor CIR model. *SAAJ* **20**, 109–47. DOI: <http://dx.doi.org/10.4314/saaj.v20i1.5>
- Farmer GJ (2002). Deficiencies in the theory of free-knot and variable-knot spline graduation methods with specific reference to the ELT 14 males graduation. *SAAJ* **2**, 69–82
- Flint E & Maré E (2017). Estimating option-implied distributions in illiquid markets and implementing the Ross recovery theorem. *SAAJ* **17**, 1–28. DOI: <http://dx.doi.org/10.4314/saaj.v17i1.1>
- Flint E & Maré E (2019). Regime-based tactical allocation for equity factors and balanced portfolios. *SAAJ* **19**, 27–52. DOI: <http://dx.doi.org/10.4314/saaj.v19i1.2>
- Flint EJ, Ochse ER & Polakow DA (2014). Estimating long-term volatility parameters for market-consistent models. *SAAJ* **14**, 19–72. DOI: <http://dx.doi.org/10.4314/saaj.v14i1.2>
- Flint E, Seymour A & Chikurunhe F (2020). Defining and measuring portfolio diversification. *SAAJ* **20**, 17–48. DOI: <http://dx.doi.org/10.4314/saaj.v20i1.2>
- Foroughi K, Jones IA & Dardis A (2003). Investment guarantees in the South African life insurance industry. *SAAJ* **3**, 29–75
- Ganz MD (2012). The effect of SAM on the South African medical-scheme environment: a quantitative analysis. *SAAJ* **12**, 65–96. DOI: <http://dx.doi.org/10.4314/saaj.v12i1.3>
- Georgiopoulos N (2017). A closed-form approximation for deriving expected losses in excess loss life reinsurance. *SAAJ* **17**, 29–42. DOI: <http://dx.doi.org/10.4314/saaj.v17i1.2>
- Govender P, Kambaran N, Patchett N, Ruddle A, Torr G & Van Zyl, N (2007). Poverty and inequality in South Africa and the world. *SAAJ* **7**, 117–60

- Harris R & Besesar S (2021). Anti-selection in voluntary health insurance markets: A focus on medical schemes in South Africa. *SAAJ* **21**, 93–118. DOI: <https://dx.doi.org/10.4314/saaj.v21i1.5>
- Hong L & Zou H (2015). Jump tests for semimartingales. *SAAJ* **15**, 93–108.
DOI: <http://dx.doi.org/10.4314/saaj.v15i1.4>
- Jeaven H, Wapnick R & Carswell MBJ (2021). The impact of giving and receiving remittances on life insurance purchases. *SAAJ* **21**, 27–47. DOI: <https://dx.doi.org/10.4314/saaj.v21i1.2>
- Johnson LF & Dorrington RE (2007). The potential effect of an HIV/AIDS vaccine in South Africa. *SAAJ* **7**, 49–72
- Kijko A, Smit A & Van de Coolwijk N (2015). A scenario approach to estimate the maximum foreseeable loss for buildings due to an earthquake in Cape Town. *SAAJ* **15**, 1–30.
DOI: <http://dx.doi.org/10.4314/saaj.v15i1.1>
- Kilian CG (2020). An investigation of an overlap in penalty calculations: profit commission in reinsurance treaties versus profit commission in binder agreements for underwriting managers. *SAAJ* **20**, 1–16. DOI: <http://dx.doi.org/10.4314/saaj.v20i1.1>
- Koch RJ (2011). Damages for personal injury and death: legal aspects relevant to actuarial assessments. *SAAJ* **11**, 111–33. DOI: <http://dx.doi.org/10.4314/saaj.v11i1.4>
- Koning FF, Swanepoel JP, Brits JD and Maré E (2022). Suitability of the 2.5% net discount rate for quantum of damage calculations in South Africa. *SAAJ* **22**, 1–28. DOI: <http://dx.doi.org/10.4314/saaj.v22i1.1>
- Levendis A & Maré E (2022). An economic scenario generator for embedded derivatives in South Africa. *SAAJ* **22**, 79–118. DOI: <http://dx.doi.org/10.4314/saaj.v22i1.4>
- Lowther MW (2004). Exercising actuarial discretion in the pricing of transfer values. *SAAJ* **4**, 63–95
- Lowther MW (2011). Promoting quality in the actuarial assessment of quantum of damages in South Africa. *SAAJ* **11**, 85–110. DOI: <http://dx.doi.org/10.4314/saaj.v11i1.3>
- Lowther MW (2022). ‘Where angels fear to tread’—Reflections on the role of an actuary as expert witness in the Land Claims Court. *SAAJ* **22**, 29–49. DOI: <http://dx.doi.org/10.4314/saaj.v22i1.2>
- Lowther MW & McMillan W (2006). Planning lifelong professionalisation learning for actuaries. *SAAJ* **6**, 1–17
- Lowther MW & McMillan WJ (2014). Authentic professional development: key to quality service delivery. *SAAJ* **14**, 1–18. DOI: <http://dx.doi.org/10.4314/saaj.v14i1.1>
- Lowther MW, McMillan WJ & Venter F (2009). Education for actuarial quality must develop more than technical competence. *SAAJ* **9**, 53–75
- Lowther MW & Mort JWT (2002). Managing actuaries’ professional risk. *SAAJ* **2**, 29–52
- Lowther MW & Mort JWT (2016). Towards best practice in the actuarial assessment of claims for maintenance against deceased estates. *SAAJ* **16**, 127–41.
DOI: <http://dx.doi.org/10.4314/saaj.v16i1.5>
- Maitland AJ (2001). An empirical approach to immunization in South Africa. *SAAJ* **1**, 119–38
- Maitland AJ (2002). Interpolating the South African yield curve using principal-components analysis: a descriptive approach. *SAAJ* **2**, 129–45
- Maitland AJ (2010). A multiple Markov switching model for actuarial use in South Africa. *SAAJ* **10**, 71–108

- Martin M & Hayes M (2013). Operational risk management: practical implications for the South African insurance industry. *SAAJ* **13**, 39–95. DOI: <http://dx.doi.org/10.4314/saaj.v13i1.3>
- McLeod HD (2005). Mutuality and solidarity in healthcare in South Africa. *SAAJ* **5**, 135–67
- McLeod HD, Achmat Z & Stein AM (2003). Minimum benefits for HIV/AIDS in South African medical schemes. *SAAJ* **3**, 77–112
- McLeod HD, Slattery PG & Van den Heever AM (2001). The use and abuse of reinsurance in medical schemes. *SAAJ* **1**, 95–117
- Molloy L & Ronnie L (2020). Sustaining the life insurance industry in the Fourth Industrial Revolution. *SAAJ* **20**, 81–107. DOI: <http://dx.doi.org/10.4314/saaj.v20i1.4>
- Mourik T (2018). Mortality risks, reinsurance and risk-based supervision. *SAAJ* **18**, 1–15. DOI: <http://dx.doi.org/10.4314/saaj.v18i1.1>
- Ngugi A, Maré E & Kufukunesu R (2015). Pricing variable annuity guarantees in South Africa under a Variance-Gamma model. *SAAJ* **15**, 131–70. DOI: <http://dx.doi.org/10.4314/saaj.v15i1.6>
- O'Malley BR, Dorrington RE, Jurisich SC, Valentini JA, Cohen TM & Ross BJ (2005). An investigation of the mortality of South African assured lives, 1995–1998. *SAAJ* **5**, 27–59
- Plaks S & Butler MJB (2012). Access to public healthcare in South Africa. *SAAJ* **12**, 129–64. DOI: <http://dx.doi.org/10.4314/saaj.v12i1.5>
- Plantinga AA, Corubolo D & Clover R (2015). Catastrophe modelling: deriving the 1-in-200-year mortality shock for a South African insurer's capital requirements under Solvency Assessment and Management. *SAAJ* **15**, 51–92 [print]. Online version with full appendices at DOI: <http://dx.doi.org/10.4314/saaj.v15i1.3>
- Polakow DA, Dunne TT & Whitworth JAG (2001). Parameterisation of expected residual lifetime after seroconversion in a Ugandan sample population. *SAAJ* **1**, 35–61
- Ramjee S, Kooverjee A & Dreyer KA (2013). The construction of a price index for contributions to South African open medical schemes. *SAAJ* **13**, 1–19. DOI: <http://dx.doi.org/10.4314/saaj.v13i1.1>
- Ramjee S, Sibiyi FG & Dreyer KA (2013). The gender profile of the South African actuarial profession. *SAAJ* **13**, 21–37. DOI: <http://dx.doi.org/10.4314/saaj.v13i1.2>
- Ranchod S, Abraham M & Bloch J (2015). An actuarial perspective on healthcare expenditure in the last year of life. *SAAJ* **15**, 31–49. DOI: <http://dx.doi.org/10.4314/saaj.v15i1.2>
- Ranchod S, Childs B, Abraham M & Taylor R (2016). International benchmarking of hospital utilisation: how does the South African private sector compare? *SAAJ* **16**, 69–90. DOI: <http://dx.doi.org/10.4314/saaj.v16i1.3>
- Raubenheimer H & Kruger MF (2010). Generating interest-rate scenarios for fixed-income portfolio optimisation. *SAAJ* **10**, 1–42
- Raubenheimer H & Kruger MF (2010). A stochastic-programming approach to integrated asset and liability management of insurance products with guarantees. *SAAJ* **10**, 43–70
- Reddy TL & Thomson RJ (2011). The capital-asset pricing model: the case of South Africa. *SAAJ* **11**, 43–84. DOI: <http://dx.doi.org/10.4314/saaj.v11i1.2>
- Rusconi RD (2005). Saving for retirement in South Africa: charges to the consumer. *SAAJ* **5**, 61–133
- Rusconi R (2020). The contribution of South Africa's insurers to systemic risk: thoughts for policy-makers. *SAAJ* **20**, 149–210. DOI: <http://dx.doi.org/10.4314/saaj.v20i1.6>

- Rusconi, RD, Beyers FJC & Walters, NM (2023). The contribution of insurers to systemic risk: A practical framework for regulators. *SAAJ* **23**, 23–58. DOI: <http://dx.doi.org/10.4314/saaj.v23i1.2>
- Şahin Ş & Levitan S (2020). A stochastic investment model for actuarial use in South Africa. *SAAJ* **20**, 49–79. DOI: <http://dx.doi.org/10.4314/saaj.v20i1.3>
- Schriek KA, Lewis PL, Clur JC & Dorrington RE (2013). The mortality of members of group schemes in South Africa. *SAAJ* **13**, 97–142. DOI: <http://dx.doi.org/10.4314/saaj.v13i1.4>
- Siriram C & Harris R (2023). Applications of advanced analytics in healthcare. *SAAJ* **23**, 1–22. DOI: <http://dx.doi.org/10.4314/saaj.v23i1.1>
- Slattery PG & Kemp HJ (2007). Options for the development of the education and professional qualification of South African actuaries. *SAAJ* **7**, 1–48
- Smith ML, Beyers FJC & De Villiers JP (2016). A method of parameterising a feed forward multi-layered perceptron artificial neural network, with reference to South African financial markets. *SAAJ* **16**, 35–67. DOI: <http://dx.doi.org/10.4314/saaj.v16i1.2>
- Strugnell D & Ranchod S (2017). Throughput in the UCT Actuarial Science programme: a microcosm of the profession's transformation challenge. *SAAJ* **17**, 43–72. DOI: <http://dx.doi.org/10.4314/saaj.v17i1.3>
- Strydom ML, Corubolo D & Nel C (2016). Changes in mortality of people living with HIV in South Africa and their potential implications for life assurers. *SAAJ* **16**, 1–33. DOI: <http://dx.doi.org/10.4314/saaj.v16i1.1>
- Taljaard BH & Maré E (2019). Considering the use of an equal-weighted index as a benchmark for South African equity investors. *SAAJ* **19**, 53–70. DOI: <http://dx.doi.org/10.4314/saaj.v19i1.3>
- Terblanche W (2009). Demand for actuarial resources in South Africa. *SAAJ* **9**, 1–52
- Thomson RJ (2006). A typology of models used in actuarial science. *SAAJ* **6**, 19–36
- Thomson RJ (2010). Modelling the market in a risk-averse world: the case of South Africa. *SAAJ* **10**, 109–36
- Thomson RJ (2011). The arbitrage-free equilibrium pricing of liabilities in an incomplete market: application to a South African retirement fund. *SAAJ* **11**, 1–41. DOI: <http://dx.doi.org/10.4314/saaj.v11i1.1>
- Thomson RJ & Posel DB (2002). The management of risk by burial societies in South Africa. *SAAJ* **2**, 83–128
- Thomson RJ & Reddy TL (2013). The capital-asset pricing model reconsidered: tests in real terms on a South African market portfolio comprising equities and bonds. *SAAJ* **13**, 221–63. DOI: <http://dx.doi.org/10.4314/saaj.v13i1.7>
- Van Appel V, Maré E and Van Niekerk A (2021). Quantitative guidelines for retiring (more safely) in South Africa. *SAAJ* **21**, 75–91. DOI: <https://dx.doi.org/10.4314/saaj.v21i1.4>
- Van Zyl N & Van Zyl DJJ (2016). The impact of behavioural economics and finance on retirement provision. *SAAJ* **16**, 91–125. DOI: <http://dx.doi.org/10.4314/saaj.v16i1.4>
- Walters NM, Beyers FJC, Van Zyl AJ & Van den Heever RJ (2018). A framework for simulating systemic risk and its application to the South African banking sector. *SAAJ* **18**, 99–133. DOI: <http://dx.doi.org/10.4314/saaj.v18i1.5>
- Wessels T & De Klerk, JJ (2023). Technical experts as managers and servant leaders. *SAAJ* **23**, 59–101. DOI: <http://dx.doi.org/10.4314/saaj.v23i1.3>

- Whittaker GA (2018). The Life Esidimeni arbitration and the actuarial quantification of constitutional damages. *SAAJ* **18**, 71–97. DOI: <http://dx.doi.org/10.4314/saaj.v18i1.4>
- Whittaker GA (2021). A history and forecast of the South African life tables No. E1 to No. E9. *SAAJ* **21**, 1–25. DOI: <https://dx.doi.org/10.4314/saaj.v21i1.1>
- Whittaker GA (2022). The actuary as *amicus curiae*. *SAAJ* **22**, 51–78. DOI: <http://dx.doi.org/10.4314/saaj.v22i1.3>
- Whittaker GA, Naidoo K & Lawrence, M (2023). Towards the development of a three-state Markov chain model of working life expectancy in South Africa. *SAAJ* **23**, 103–53. DOI: <http://dx.doi.org/10.4314/saaj.v23i1.4>

EDITORIAL POLICY

The editorial policy of the *South African Actuarial Journal (SAAJ)* is set out in the Instructions to Authors of Papers for Publication in the South African Actuarial Journal, which may be downloaded from the *SAAJ* web page at:

www.actuarialsociety.org.za/Professionalresources/SAActuarialJournal.aspx
via the hypertext link: Instructions to Authors.

The *Journal's* Guidelines on Style are also available there.

PUBLICATION DETAILS

Articles published in this journal are available for open access, free to download, from the SAAJ web page at

www.actuarialsociety.org.za/Professionalresources/SAActuarialJournal.aspx

They are also available by subscription from Sabinet at

<https://journals.co.za/content/journal/actu/browse>

Articles may also be ordered electronically from African Journals OnLine (AJOL) at

www.ajol.info

The AJOL link <http://www.ajol.info/index.php/saaj> gives direct access to the *SAAJ* homepage on AJOL's website



Contents

REFEREED PAPERS

C SIRIRAM AND R HARRIS	
Applications of advanced analytics in healthcare	1
RD RUSCONI, FJC BEYERS AND NM WALTERS	
The contribution of insurers to systemic risk: A practical framework for regulators	23
T WESSELS AND JJ DE KLERK	
Technical experts as managers and servant leaders	59
GA WHITTAKER, K NAIDOO AND M LAWRENCE	
Towards the development of a three-state Markov chain model of working life expectancy in South Africa	103

CUMULATIVE INDEX	155
------------------	-----

ISSN 1680-2179



9 771680 217002