DOCTOR OF PHILOSOPHY IN MANAGEMENT

ESSAYS ON WARRANTY CLAIMS

By

AKSHITA SRIVASTAVA

भारतीय प्रबंध संस्थान बेंगलूर
INDIAN INSTITUTE OF MANAGEMENT
BANGALORE

2022

DOCTOR OF PHILOSOPHY IN MANAGEMENT

ESSAYS ON WARRANTY CLAIMS

By

Akshita Srivastava

A Dissertation submitted in Partial Fulfillment of the Requirements for the degree of Doctor of Philosophy at

INDIAN INSTITUTE OF MANAGEMENT BANGALORE

2022

Prof. Ananth Krishnamurthy
Chairperson
Doctoral Programme

Prof. U Dinesh Kumar
Chairperson
Dissertation Advisory Committee

Members of the Dissertation Advisory Committee

1.	Prof. U Dinesh Kumar	Chairperson
2.	Prof. Srinivas Prakhya	Member
3.	Prof. Rajluxmi V Murthy	Member

Dedication

I dedicate my thesis work to my husband Mr. Rajiv Mukul and my son Hemang, who fully supported me throughout my PhD journey.

This work is also dedicated to the memory of my beloved mother who always prayed for my success.

Last but not the least, I would like to thank my elders and the almighty God whose blessings guided me in every step of my journey.

ACKNOWLEDGEMENTS

Words cannot express my gratitude to the professor and chair of my committee, Prof. U Dinesh Kumar for his patience and invaluable feedback. He provided me with constant guidance and was always willing to assist me in every stage of my thesis.

I also could not have undertaken this journey without my defense committee members, Prof. Srinivas Prakhya and Prof. Rajluxmi V Murthy, who generously provided their comments and helped me through my thesis in every possible way.

I would also like to show my gratitude to my external review committee members, Prof. Ramanathan and Dr. Vimala Rani for their time and patience in reviewing my thesis.

I would also like to thank the Data Center and Analytics team of IIMB, who provided me with the data used in the study. During the engaging discussion with the DCAL members, I was able to clarify my doubts regarding the data.

Lastly, I want to thank my family for believing in me and supporting me.

Table of Contents

LIST OF TABLES

LIST OF TABLES

List Of Figures

ACRONYMS

$i=1,2\ldots. N$	Index for the individuals
$l=1,2\ldots. L$	Index for the explanatory variables
$s=1,2\ldots. S$	Index for the latent classes
n_i	Number of claims for individual i in time period t_i
x_{il}	Value of the l^{th} explanatory variable for the i^{th} individual
b	Scale parameter
γ	Shape parameter
p	Failure mode
K	Number of latent segments
t_p	Duration time on category p
π_k	Mixing proportions corresponding to K latent segments
β	Regression parameters
X	Vector of covariates
h_{ij}	Hazard of the j^{th} individual from cluster i
Y	Matrix of the indicator variables
λ	Mean event rate

Abstract

Warranty management is a critical decision for consumer durables, automobiles and capital equipment manufacturers. Original equipment manufacturers (OEMs) must decide on warranty duration, exclusions on warranty and extended warranty policy. These decisions can have a significant impact on profitability. Many companies encounter an unexplained gap between warranty accruals and actual warranty costs. One of the reasons behind this is the 'unexplained variation', which if accounted for, will provide a valuable understanding of warranty claims and improve warranty prediction.

The unexplained variability in warranty claims can occur due to various factors. One of the most important causes of the variation are the usage and the operating conditions. There is extensive literature on known causes of variability such as usage and risk attitudes (i.e., whether a customer is risk averse, risk neutral or risk loving). Factors such as the operating conditions are difficult to incorporate in the model building process since they are unknown. Such hidden causes either need to be discovered or modelled appropriately for better warranty management. Therefore, through this thesis, we have first tried to uncover the latent factors that impact warranty claims and the survival of the components. Second, we have proposed wholistic modelling approaches to incorporate those factors into the model-building process.

We have divided our work into three different essays. The first essay deals with modelling variability in warranty claim counts itself. Although neglected in the literature, the variability in warranty claim counts can provide useful information about the underlying hidden components or the subpopulations. This essay presents a hybrid approach consisting of factor identification and model development and employs an integrated framework to better model warranty claims. In this essay, we group the claim population into clusters or components, which behave similarly with respect to location, climate and urbanization. Then, a latent class Poisson regression methodology is proposed. The cluster characteristics thus obtained are entered into the modelling framework using the finite mixture modelling approach, which gives a better fit than the existing models, thereby improving prediction.

In the second essay, we try to uncover the latent segments in the population that share dependence effects, owing to the unobserved risk factors. This would help the manufacturer identify segments in the population that are more likely to result in claims or are more 'frail' than the others. This is achieved through a two-step process. First, the hidden components have been obtained via clustering of survival data using the Weibull mixture model approach. Such an approach will not only serve as representative for unobservable covariates via cluster membership but also provide a way by which the product units can be classified into different subpopulations prior to statistical lifetime modelling. The second step of the approach incorporates cluster membership into the shared frailty model framework. Thus, this essay proposes a novel approach to obtain those segments in the population which share similar risks owing to the unobserved factors and are highly correlated.

The third essay studies the impact of dealer characteristics on time between claims and tries to identify the role of dealers in achieving the 'right first time' objective. In addition, this essay also provides a way to rank the dealers based on their unobserved characteristics using empirical Bayes methods and consequently enables best practices to be followed across the dealers. To the best of my knowledge, this is the first study examining dealer's role on time between claims and provides a method to compare their relative performance.

The contribution of this thesis is to provide the manufacturer with a new perspective to look into different causes of variability apart from previously considered causes, i.e., usage and risk attitudes. Further, it provides a means to incorporate those causes in the model-building process for a better warranty management.

Keywords: Finite mixture modelling, sub-populations, warranty claims, variation, heterogeneity.