Handling Non-Normal Data in Individual and Moving Range Control Charts: An Application to Raw Rubber Manufacturing Process Data

by

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M.Phil 2016

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Thesis submitted to the University of Sri Jayewardenepura

for the award of the Degree of Master of Philosophy in Statistics

on 29th March 2016

Candidate's Declaration

The work described in this thesis was carried by me under the supervision of Prof. B. M. S. G. Banneheka and Dr. Keminda Herath and a report on this has not been submitted in whole or in part to any university or any other institution for another Degree/Diploma. I certify that all additions and amendments have been incorporated in the thesis in accordance with the comments and suggestions of the examiners.

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Date : 12/06/2017

Supervisors' Declaration

We certify that the above statement made by the candidate is true and that this thesis is suitable for submission to the University for the purpose of evaluation and also certify that all additions and amendments have been incorporated in the thesis by the candidate in accordance with the comments and suggestions of the examiners under our supervision.

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Date : 12/06/2017

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Date : 12/06/2017

"Where I am Today, That's Because of You All"

Affectionately Dedicated

To

All My Respectable Teachers,

My Beloved Grandparents, Parents and Sister

My Dearest Husband

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LIST OF ABREVIATIONS

AD	-	Anderson-Darling
ARL	-	Average Run Length
CL	-	Center Line
CM	-	Cramer-von Mises
CUSUM	-	Cumulative Sum
DMAIC	-	Define, Measure, Analyze, Improve and Control
EWMA	-	Exponentially Weighted Moving Average
HDD	-	Hard Disk Drive
I- chart	-	Individual chart
I-MR	-	Individual and Moving Range
ISO	-	International Organization for Standardization
KS	-	Kolmogorov-Smirnov
LCL	-	Lower Control Limit
LF	-	Lilliefors
MCUSUM	-	Multivariate Cumulative Sum
MEWMA	-	Multivariate Exponentially Weighted Moving Average
MR-chart	-	Moving Range chart
OC	-	Operating Characteristics
OCP	-	Out of Control Points
PC	-	Pearson chi-square
Q-Q	-	Quantile - Quantile
RRISL	-	Rubber Research Institute of Sri Lanka
RSS	-	Ribbed Smoked Sheet
Rwui	-	R Web User Interface
SF	-	Shapiro-Francia
SPC	-	Statistical Process Control
SW	-	Shapiro-Wilk
TSR	-	Technically Specified Rubbers
UCL	-	Upper Control Limit

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ACKNOWLEDGEMENTS

Though only my name appears on the cover of this dissertation, a great many people have contributed to its production. I owe my gratitude to all those people who have made this dissertation possible.

First and foremost I would like to express my deepest sense of **G**ratitude to my main supervisor, Prof. B.M.S.G. Banneheka, Professor, Department of Statistics, Faculty of Applied Sciences, University of Sri Jayewardenepura for accepting me as his M-Phil student. I have been amazingly fortunate to have a supervisor who guided me to actively explore problems and challenges in order to acquire a deeper knowledge and at the same time who gave me the guidance to recover when my steps faltered. During my research, he engaged me in new ideas, and demanded a high quality of work in all my endeavors. Prof. B.M.S.G. Banneheka is one of the supervisors/teachers who truly made a difference in my career life also. It was under his tutelage that I developed a focus and became interested in teaching and researching. I doubt that I will ever be able to convey my appreciation fully, but I owe him my eternal gratitude for the great effort he put into training me in the research field, and also for the continuous support of my M-Phil research, for his patience, motivation, enthusiasm, and immense knowledge.

I am also deeply grateful to my external supervisor, Dr. Keminda Herath, Senior Lecturer, Department of Agri-Business Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka who has been always there to listen and give practical advice. His insightful comments and constructive criticisms at different stages of my research were thought-provoking and they helped me to focus my ideas. He provided me with direction, encouragement, enthusiasm, intellectual freedom in my work and became more of a mentor and friend, than a supervisor. A very special thanks goes out to Dr. Keminda Herath whose understanding and patience added considerably to my post graduate research experience.

I am very much grateful to all the people I have met along the way and have contributed to the development of my research. In particular I wish to extend my sincere gratitude Dr. Susantha Siriwardena, Head, Raw Rubber Process Development and Chemical Engineering Department, Rubber Research Institute of Sri Lanka (RRISL) and Dr. (Mrs) Wasana Wijesuriya, Head, Biometry Section, RRISL for providing necessary information to carry out my research. My appreciation goes to Mr. Vidura Abeywardene

at Biometry section of RRISL who helped me to collect necessary data to complete this research successfully. Further, I would like to show my gratitude to Mr. R V K S D Livera, Regional manager of Kotagala Plantation, Mr. Sunil Sepala and office staff of Payagala rubber factory for their priceless assistance to obtain necessary data and information regarding the crepe rubber manufacturing process. I am so glad to express my heart-felt gratitude for the great help rendered to me by Mr. Richard Newton, the person who established Rwui by replying my e-mails regarding the problems I faced when creating Rwui web application in this research.

I must also acknowledge Mrs. K A Dilini T Kulawansa, former Head and Dr. K S D Fernando, current Head of the Department of Computational Mathematics, Faculty of Information Technology, University of Moratuwa for providing me with encouragement and necessary freedom throughout this endeavor in order to finish my M-Phil successfully.

My dear friends, Priyanga, Thiyanga and Hasanthi (Anu) have helped me to stay sane throughout this research. I greatly value and appreciate their friendship. I cannot forget Priyanga's mother's kind words which helped me to focus on my research with undivided attention. A very big thanks should go to Priyanga's mother. Their support and encouragement whenever I was in need helped me to overcome setbacks and to stay focused on my research.

Most importantly, none of this would have been possible without the love and patience of my family. My deepest gratitude goes to my parents for their unflagging love and unconditional support throughout my life and my studies. You made me live the most unique, magic and carefree childhood that has made me who I am now. My profound gratitude from my deep heart is to my dearest husband who has been a constant source of love, concern, support and strength all these years. I have been very much fortunate to have a husband like you and your unconditional love and support made me free in order to focus on my studies and complete this research successfully. Last but not least I must appreciate the great support rendered to me by my sister to make this endeavor a success.

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ABSTRACT

This research focused on control charting for quality assurance of crepe rubber manufacturing process in Sri Lanka. There is lack of interest in applying quality tools for process monitoring in crepe rubber industry due to the crude nature of this process. However, some researchers have identified individual and moving range (I-MR) control charts as a suitable statistical process control (SPC) technique for rubber data. When applying control charting in SPC, normality assumption of data should be considered since performances of the control charts are very much sensitive to departures from normality. Rubber data also show a significant deviation from normal assumption. No comprehensive study has been done to establish a proper practice for laymen to use I-MR charts in crepe rubber industry when data are non-normal. Therefore, the main objective of this research was to find a solution for non-normality issue of data on I-MR control charting and hence to introduce a feasible way to apply I-MR charts for process improvement in crepe rubber manufacturing industry.

We have identified Johnson transformation as a suitable method to handle non-normality issue of data; other simple transformations and distribution fitting did not work for rubber data. By incorporating Johnson transformation, a feasible way to use I-MR charts was developed. Evaluation of the method was based on Monte Carlo simulation and probability of type I error, average run length and the power of control charts were estimated under the simulation study. We have evaluated the performances of I-MR charts for non normal data generated from different non normal distributions.

In the case of factory (rubber) data, data were generated from the empirical distribution of factory data in order to evaluate the performance of I-MR charts with respect to the practical situation. In this research, data were collected from two sites where the crepe rubber manufacturing process runs; Dartonfield rubber factory and Payagala rubber factory. Data collected during the period of two years commencing from year 2004 at Dartonfield factory and data collected during the period from September 2010 to August 2011 at Payagala factory were used.

The results of simulation study clearly indicate the high sensitivity of I-MR charts to non-normality. I chart developed for Johnson transformed data produces relatively low values for probability of type I error. Small values of average run length when the process is actually in control (ARL_0) for original data strongly show the bad impact of not addressing non normality issue for control charting in SPC. Same figures which are shown for I chart, can be seen for MR chart also, but comparatively MR chart gets lower values for ARL_0 for Johnson transformed data than I chart obtains. It indicates the low effectiveness of MR chart for process monitoring when compared to the effectiveness of I chart. Further, I chart developed for Johnson transformed data produces a power curve which is aligned with the theoretically accepted power curve of standard 3-sigma I chart. Therefore, the method of applying I-MR charts by incorporating Johnson transformation can be recommended for non normal data in any industry.

Finally, a user friendly web application that can be used by any industry person to develop I-MR charts for process monitoring task when the process generates non normal data has been created by using Rwui (R web user interface) which is a web application which can be used to create user friendly web interfaces for R scripts.