

**AN OPTIMIZATION MODEL FOR MULTI-OBJECTIVE
VEHICLE ROUTING PROBLEM FOR PERISHABLE
GOODS DISTRIBUTION**

Madushan Fernando

218017J

Degree of Master of Science

Department of Transport and Logistics Management

University of Moratuwa

Sri Lanka

August 2022

**AN OPTIMIZATION MODEL FOR MULTI-OBJECTIVE
VEHICLE ROUTING PROBLEM FOR PERISHABLE
GOODS DISTRIBUTION**

Madushan Fernando

218017J

Degree of Master of Science

Department of Transport and Logistics Management

University of Moratuwa

Sri Lanka

August 2022

DECLARATION OF ORIGINALITY

I declare that this is my own work, and this thesis/dissertation does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any other University or institute of higher learning and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

I hereby also grant to the University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature:

Date: 22nd August 2022

UOM Verified Signature

STATEMENT OF THE SUPERVISOR

The above candidate has carried out research for the Degree of Master of Science under my supervision.

Names of supervisors: Dr. Amila Thibbotuwawa

Dr. H.N. Perera

Signatures of Supervisors:

Date: 22nd August 2022

UOM Verified Signature

UOM Verified Signature

Abstract

Vehicle Routing Problem (VRP) is a well-studied area of operations research that has resulted in significant cost savings in global transportation. The primary goal of the VRP is to find the best route plan that minimizes the total distance traveled. The current study used VRP to solve the problem of fresh Agri products distribution in retail chains. With the advancement of computation power, researchers pay more attention to incorporating real-world characteristics when developing VRP, making it more practical for use in real-world applications. Existing literature identifies a research gap in richer problems that use real-world characteristics concurrently. This study created an integrated bi-objective VRP model that focused on resource optimization, order scheduling, and route optimization all at the same time. Two objectives aim to minimize distribution costs while ensuring product deliveries to retail outlets on time. To improve real-world applicability, the model incorporated multiple real-world characteristics simultaneously. All the algorithms were developed using an open-source optimization library called OR-tools.

This research compared several heuristics and metaheuristic methods respectively, to obtain the IBFS (Initial Basic Feasible Solutions) and iterative improvements. Thereafter, best performing heuristic method (savings algorithms) and metaheuristic method (guided local search) were hybridized to develop the proposed two-phase solution method. All the solution algorithms and the developed VRP model were tested using the data obtained from one of the largest retail chains in Sri Lanka. Numerical experiments show the efficiency of the proposed solution algorithm in solving a real-world VRP problem. Further, numerical experiments show that the proposed VRP model has achieved a 16% saving in daily distribution cost while ensuring on-time deliveries to 95% of the retail outlets. Further, on-time deliveries of fresh Agri products ensure the freshness conditions. The developed VRP model is efficient to use as an operational planning tool for planning distribution operations in retail chains.

Keywords:

Vehicle Routing Problem, Perishable goods distribution, Retail supply chain, Heuristic methods, Metaheuristic methods, Real-world application

ACKNOWLEDGEMENT

First and foremost, I would like to express my heartfelt gratitude to Dr. Amila Thibbotuwawa and Dr. Niles Perera for providing this wonderful opportunity to conduct master's research under their supervision. I consider myself extremely fortunate to be conducting research under the supervision of two experts in this field. My two supervisors' guidance and support throughout the research helped me get through this difficult milestone. The motivation I gain from them will be extremely beneficial to my future research endeavors.

I would like to express my heartfelt appreciation to Dr. T. Sivakumar, post-graduate research coordinator at the Department of TLM, for his guidance and assistance. I would like to extend my sincere gratitude to Senior Prof. Amal S. Kumarage, Former Head and Founder of the Department of TLM of the University of Moratuwa, and Prof. A.A.D.A.J. Perera, the current Head of the Department, for allowing me to conduct the degree program. I would also like to thank the Department of Transport and Logistics Management's academic and non-academic staff for their assistance.

Further, I would like to extend my gratitude to Mr. Pernal Daksith for his immense support in data collection from the local company. Also, I would like to thank Mr. Madhava Jayalath and Mr. H.H.H.R. Chamara for their support during the data collection process. I gratefully acknowledge Grant IDs SRC/LT/20202/20 and SRC/LT/2021/22, Senate Research Committee, University of Moratuwa, Sri Lanka, for funding for my research. I also would like to thank my friends, and colleagues at the Center for Supply Chain, Operations and Logistics Optimization (SCOLO), for their encouragement and support.

Most importantly, I would like to express my gratitude to my parents, brother, wife, sister-in-law, and parents-in-law for their love and unwavering support. I especially need to remember my niece and nephew's love and affection. I will not be able to complete this milestone without the support of my family.

TABLE OF CONTENTS

DECLARATION OF ORIGINALITY	i
STATEMENT OF THE SUPERVISOR	ii
Abstract	iii
ACKNOWLEDGEMENT	iv
LIST OF FIGURES	vii
LIST OF TABLES	viii
LIST OF ABBREVIATIONS	ix
1. INTRODUCTION	1
1.1. Background and Motivation	1
1.2. Significance of the Research	4
1.3. Structure of the Thesis	5
2. LITERATURE REVIEW	6
2.1. Nature of the Objectives of VRPFPG Models	6
2.2. Problem Characteristics	8
2.3. Solution Approaches	10
2.4. Close-Open Mixed Vehicle Routing Problem	14
2.5. Research Objectives Development	15
3. METHODOLOGY	17
3.1. Model Formulation	17
3.1.1. Overview	17
3.1.2. Notations	19
3.1.3. Assumptions	20
3.1.4. Mathematical Model	20
3.2. Data Collection	24
3.3. Model Implementation	26
3.4. Apply Solution Approaches	28
3.4.1. Initial Solution Approaches	29
3.4.2. Metaheuristics	29
3.5. The Proposed Two-Phase Solution Method	31
4. RESULTS AND DISCUSSION	33
4.1. Conceptual Framework	33
4.2. Comparison of Solution Techniques	34
4.2.1. Heuristic Methods	34

4.2.2.	Metaheuristic Methods	35
4.2.3.	Benchmark Results of Proposed Two-Phase Solution Method	37
4.3.	Test the Model	38
4.3.1.	Effectiveness of Allocating Retail Outlets to Distribution Centers	39
4.3.2.	Effectiveness of Retail Outlets' Order Allocation	42
4.3.3.	Optimal Route Plan	43
4.4.	Model Extension	45
5.	CONCLUSION	47
5.1.	Research Contributions	47
5.2.	Practical Implication	49
5.3.	Research Limitations and Future Directions	50
	REFERENCES	51
	LIST OF APPENDICES	58
	Appendix-A: Location Data of Retail Chain	58
	Appendix-B: Distance Matrix	62
	Appendix-C: Time Matrix	62

LIST OF FIGURES

Figure 1-1: Research design.....	4
Figure 2-1: Nature of objective of single objective VRPFPG models.....	6
Figure 2-2: Nature of objective of multiple objective VRPFPG models.....	7
Figure 2-3: Nature of time window structure	8
Figure 2-4: Solution approaches used to solve single and multiple objective VRPFPG models respectively.....	10
Figure 2-5: Comparison of different categories of solution approaches.....	13
Figure 3-1: Model overview	18
Figure 3-2: Comparing Euclidean distance and real-driving distance.....	24
Figure 3-3: Estimate product-wise demand in terms of vegetable crates	25
Figure 3-4: Process followed to develop computer application for the proposed model.....	26
Figure 3-5: Defining the scale of the routing model.....	28
Figure 3-6: Continuous improvement process in neighborhood search method	29
Figure 4-1: Conceptual framework for the numerical experiments.....	33
Figure 4-2: Heuristic methods comparison for obtaining IBFS.....	34
Figure 4-3: Comparison of meta-heuristic methods in terms of objective value.....	35
Figure 4-4: Comparison of meta-heuristic methods in terms of computation time ...	36
Figure 4-5: Benchmark results for two-phase solution method in terms of objective value.....	37
Figure 4-6: Benchmark results for two-phase solution method in terms of computation time	37
Figure 4-7: Comparing the current practice and the proposed model in allocating distribution centers.....	39
Figure 4-8: Distribution cost saving realized through the proposed model.....	40
Figure 4-9: Truck capacity utilization realized through the proposed model	42
Figure 5-1: Sample user interface	50

LIST OF TABLES

Table 1-1: Different VRP extensions used in the research	2
Table 2-1: Keyword structure	Error! Bookmark not defined.
Table 3-1: Notations used for the model.....	19
Table 3-2: Details about the data model	27
Table 4-1: Input data for numerical experiments.....	39
Table 4-2: Fuel cost and fixed cost savings realized through the proposed model ...	41
Table 4-3: Model output	43
Table 4-4: Routes with late deliveries	44
Table 5-1: Research contributions	47

LIST OF ABBREVIATIONS

COMVRP - Closed Open Mixed Vehicle Routing Problem

CVRP - Capacitated Vehicle Routing Problem

GLS - Guided Local Search

HFVRP - Heterogenous Fleet Vehicle Routing Problem

IBFS - Initial Basic Feasible Solutions

MDVRP - Multiple Depot Vehicle Routing Problem

MOVRP - Muti Objective Vehicle Routing Problem

OR - Operations Research

OSRM - Open-Source Routing Machine

SA - Simulated Annealing

SDVRP - Split Delivery Vehicle Routing Problem

TS - Tabu Search

VRP - Vehicle Routing Problem

VRPFPG - Vehicle Routing Problem for Perishable Goods

VRPTW - Vehicle Routing Problem with Time Windows