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Comparison of Performance Evaluation of Reverse Supply Chain in Information Technology and Telecommunication Equipment Industry

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Abstract- Due to the increasing product variety and shorter life cycles, many electronic products end up in disposal sites. The development in the electronics sector is geared towards growing miniaturization, more complex and compact products, all of which stand in the way of economical and ecological recycling. These factors in addition to the inherent complexity of reverse supply chains (RSC) due to the uncertainties associated with the quantity, quality, and timing of returns make returns management all the more complicated. Information technology and telecommunication equipment industries have started to realize that RSC can be used to gain competitive advantage. Effective performance management is an important aspect of the RSC initiative, and is the key to recognizing the benefits of efficient supply chain management systems.This research spotlights on this particular problem from a information technology and telecommunication equipment industries perspective, as it poses the greatest challenges in handling returns due to the presence of high clock speed products and greater return volume and variability. In this research, Performance Evaluation Analytic for Reverse Logistics Methodology is developed to facilitate decision making from the perspective of an enterprise engaged in reverse logistics. It explores the various reverse logistics functions and product lifecycle stages. It also develops some key business strategies and performance metrics that can be employed to be successful in returns handling. Deployment of this methodology in their organizations not only provides them with a real world assessment of what strategies, reverse logistics functions, product lifecycle stages, or key performance indicators impact the Reverse Logistics Performance Value, thereby allowing them to continuously improve their returns management capabilities but also helps us to compare the efficiencies of the two organisation under study.

Keywords: reverse supply chain, shrinking, performance evaluation analytic, reverse logistics functions, strategies, product lifecycle stages, reverse logistics performance value.

I. INTRODUCTION

Reverse logistics is defined as "the process of planning, implementing and controlling the efficient, cost effective flow of materials in process inventory, finished goods and related information from the point of conception to the point of origin for the purpose of recycling value or proper disposal [1]. Reverse logistics concentrates on those streams where some value can be recovered. It is the process of managing the flow of returned products and information from the point of consumption to the point of origin. According to a recent study, reverse logistics is one of the twenty one top warehousing trends in the twenty first century (Brockmann,1999). Industries have started to realize that the reverse logistics can be used to gain competitive advantage. An evaluation framework, which incorporates determinants and dimensions of reverse logistics, would be useful in configuring the post activities associated with the EOL computers. There are number of variables affecting the reverse logistics, some of these are interdependent among each other. The objective of the paper is to develop a quantitative methodology for evaluating the reverse supply chain performance in information technology and telecommunication equipment industry and to compare the same with two case studies. The quantitative methodology was developed with the help of Analytic Network Process. Analytic Network Process (ANP) is a technique that captures the interdependencies between the criteria under consideration, hence allowing for a more systematic analysis [2]. It can allow inclusion of criteria, both tangible and intangible, which has some bearing on making the best decision. Further, many of these factors have some level of interdependency among them, thus making ANP modeling better fit for the problem under study. The ANP model presented in this paper structures the problem related to selection of an alternative for the reverse logistics option for EOL computers in a hierarchical form and links the determinants, dimensions and enablers of reverse logistics with different alternatives.

II. LITERATURE REVIEW

Stock (1992) recognized the field of reverse logistics as being relevant for business and society in general. Kopicki, Berg, Legg, Dasappa, and Maggioni (1993) paid attention to the field and pointed out opportunities on reuse and recycling. Fleischmann, Bloemhof-Ruwaard, Dekker, van der Laan, van Nunen, and Van Wassenhove (1997) had given a comprehensive review of literature of the quantitative models in reverse logistics. Reverse logistics programs in addition to the various environmental and the cost benefits can proactively minimize the threat of government regulation and can improve the corporate image of the companies (Carter & Ellram, 1998). Reverse logistics is the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal (Rogers & Tibben-Lembke, 1998). A reverse logistics defines a supply chain that is redesigned to efficiently manage the flow of products or parts destined for remanufacturing, recycling, or disposal and to effectively utilize resources (Dowlatshahi, 2000).

Thus, the reverse logistics focuses on managing flows of material, information, and relationships for value addition as well as for the proper disposal of products. Reverse logistics has been used in many industries like photocopiers (Krikke, van Harten, & Schuur, 1999a; Thierry, Salomon, Nunen, & Wassenhove, 1995; van der Laan, Dekker, & Van Wassenhove, 1999) single-use cameras (Toktay, Wein, & Stefanos, 2000), jet engine components (Guide & Srivastava 1998), cellular telephones (Jayaraman, Guide, & Srivastava, 1999), automotive parts (van der Laan, 1997) and refillable containers (Kelle & Silver, 1989). In all the cases, one of the major concerns is to assess whether or not the recovery of used products is economically more attractive than the disposal of the products [3]. Reverse logistics are also extensively practiced in the computer hardware industry. IBM and Dell Computer Corporation have embraced reverse logistics by taking steps to streamline the way they deploy old systems; and in the process make it easier for the customers to refurbish existing computers or buy new parts (Ferguson, 2000). Grenchus, Johnson, and McDonell (2001) reported that the Global Asset Recovery Services (GARS) organization of IBM's Global Financing division has integrated some of the key components of its reverse logistics network to support and enhance environmental performance. Moyer and Gupta (1997) have conducted a comprehensive survey of previous works related to environmentally conscious manufacturing practices, recycling, and the complexities of disassembly in the electronics industry. Gungor and Gupta (1999) have presented the development of research in environmentally conscious manufacturing and product recovery (ECMPRO) and provided a state-of-the-art survey of the published work in this area. Veerakamolmal and Gupta (1997) have discussed a technique for analyzing the design efficiency of electronic products, in order to study the effect of end-of-life disassembly and disposal on environment. Nagel and Meyer (1999) discuss a novel method for systematically modeling end-of-life networks and show ways of improving the existing and new systems with ecological and economical concerns. Boon, Isaacs, and Gupta (2002) have investigated the critical factors influencing the profitability of end-of-life processing of PCs. They also suggested suitable policies for both PC manufacturers and legislators to ensure that there is a viable PC recycling infrastructure. Lambert (2003) presented a state-of-the-art survey of recently available literature on disassembly sequencing and the papers closely related to this topic. Krikke, van Harten, and Schuur (1999b) have discussed a case of the recycling PC-monitors as a part of a broader pilot project at Roteb (the municipal waste company of Rotterdam, The Netherlands) where by using the model developed, it achieved a reduction of recycling costs by about 25%. Ferguson and Browne (2001) discussed the issues in EOL product recovery and reverse logistics. Knemeyer, Ponzurick, and Logar (2002) utilized a qualitative methodology to examine the feasibility of designing a reverse logistics system to recycle or refurbish EOL computers that are deemed no longer useful by their owners [7]. From the literature review, it is observed that there is not much work reported till date for multi-criteria decision making in the decision making related to reverse logistics practices in the case of EOL computers.

III. PROBLEM DESCRIPTION

The legislations and the economic benefits of reverse logistics have forced organizations to take a new look at their operations. Due to intense competition and stringent environmental regulations, it is quite difficult to sustain successful business operations just by handling the forward supply chain effectively. Hence, it is imperative that companies begin to effectively manage their reverse supply chains also, thereby developing into a successful closed loop organization. Developing accurate and consistent performance measures is critical because it directly reflects on quality of the system and its effectiveness. The development of accurate and measurable performance metrics represents a major step in adopting a holistic approach to reverse supply chain management. As the information technology and telecommunication equipment industry is more complex than other industries in terms of uncertainty of product returns, this research will concentrate specifically on the information technology and communication equipment industry namely the tronic products such as computers and laptops. tronics is the basic technology for many new products he industry. Due to the increasing product variety and rter life cycles, many electronic products end up in osal sites.

Product Life cycle length

Ferrous Scraps	Cartridges for single use cameras	
Hazardous wastes	Tires	Retailers
Syringes		Computers

Return Rate Variability →

Fig.1. Lifecycle- Variability Matrix for different industries

IV. METHODOLOGY

The case study approach was selected because it is an ideal method when a holistic, in-depth investigation is needed. This case study approach helps to gather the facts from the real world and explain the linkages between causes and effects. One such benefit is that the information provided is usually more concrete and contextual, specifically due to the in depth analysis it offers of the case being studied.

A. Algorithm

Step 1: Start

Step 2: Determine the goals and objectives of the organization pertaining to RL

Fig.2. Goals

In order to maximize the profit, one has to improve the efficiency of the system which is achieved only by measuring the performance of the system.

Step 3: Drivers of Reverse Logistics are determined

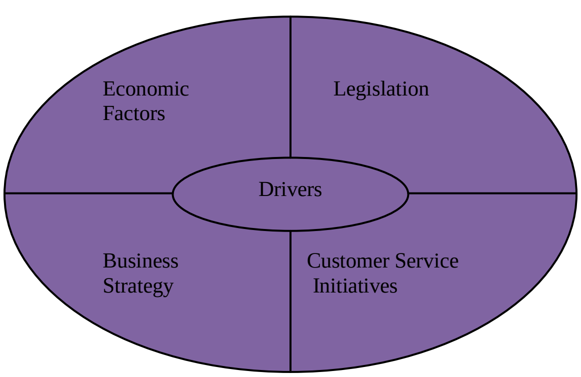

Fig.3. Drivers

Step 4: Identify the product life-cycle stages

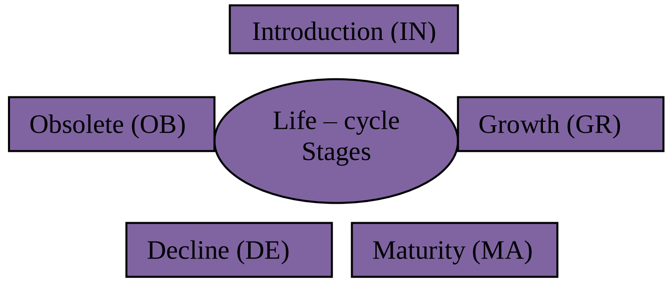

Fig.3. Life cycle stages

Step 5: Determination of competitive strategies involved in RL

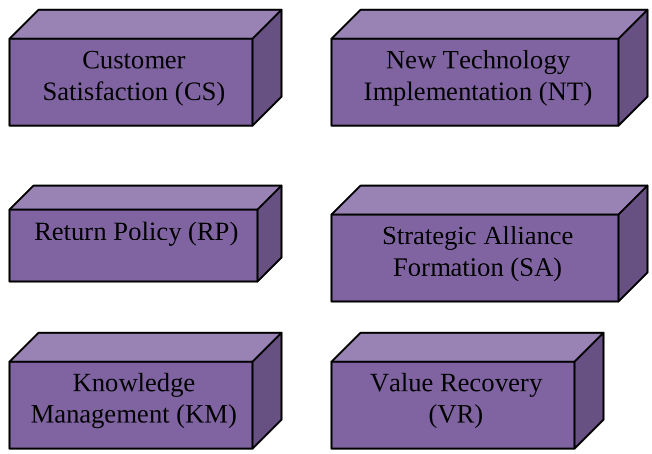

Fig 4. Strategies

Step 6: The various functions involved in RL and their performance metrices are identified

Gate Keeping (GK)	Sorting & Storing (SS)	Asset Recovery (AR)	Transportation (TN)
Return Value (RV)	Warehousing Effectiveness (WE)	Recovery Efficiency (RE)	Overall Vehicle effectiveness (VE)
Gate-keeping Effectiveness (GE)	Carrying cost percentage (RC)	Recovery Rate (RR)	Return Transit Time (RT)
		Environmental Effectiveness (EE)	

Fig 5. Functions and Performance Metrics

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Step 7: Form pair-wise matrices with respect to the inter and intra dependencies between the clusters.

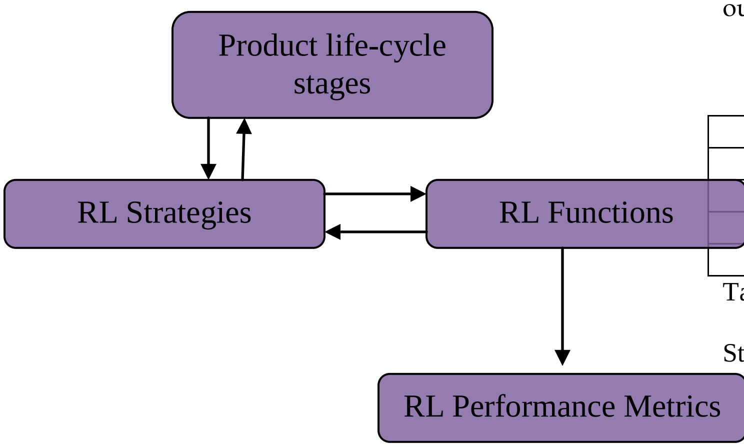

Fig 6. Cluster Relationship diagram for pair wise matrices

Therefore it is clear that pair-wise comparison matrices have to be formed between:

i) The performance metrices with respect to various functions
ii) The RL functions with respect to a particular function
iii) The RL functions with respect to various strategies
iv) The RL strategies with respect to various functions
v) The RL strategies with respect to various product life cycle stages
vi) The product life-cycle stages with respect to various strategies

Step 8 : . Once the weights are calculated, the next sub step is to determine the Z-Vector value for the reverse logistics process with respect to all the strategies

Step 9: Develop Super matrix from Pair-wise comparison matrices of interdependencies

	Life-cycle stages	**Strategies**	**Functions**
Life-cycle stages			
Strategies			
Functions			

Step 10: Converge the Super matrix using WIMS software available at http://wims.unice.fr/wims/wims.cgi. Converging is the process of multiplying the matrix by itself repeatedly till constant results are obtained. It occurs only at an odd (2k+1)th iteration (k is any integer).

Step 11: Determine the performance values at the measures for each RL function within the organization. This is found out from the Converged Super matrix

	GK	**SS**	**AR**	**TN**
GK				
SS				
AR				
TN				

Table 1 Converged Super Matrix

Step 12: Calculation of performance metrices – formulae

i) Return Value (RV)

$$RV = n * N * C$$

Where,
n is the Number of Reverse Logistics Locations
N is the Number of returned products
C is the cost of one returned product

Gate keeping Effectiveness (GE)

Gate-keeping effectiveness is a qualitative aggregate measure that helps an organization compare its practices to some of the best practices obtained from academic research and industry.

BEST PRACTICE	
Clear and visible return policies to reduce the number of defective products into the RSC	
Use of dedicated and skilled labour for return product inspection	
Use of latest equipment for checking the reliability of the product	
Use of multiple channels such as phone and internet to provide support	
Employ programs to reduce idle time of trucks and products at Gate Keeping	

Table 2. Checklist for GR

ii) Warehousing Effectiveness (WE)

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Warehousing Effectiveness is an aggregate measure of warehousing performance of an organization in handling returns.

Table 3. checklist for WE

iii) Carrying cost Percentage (RC)

$$\textbf{(RC)} = \frac{\textbf{Fixed costs + Variable costs}}{\textbf{Average Value of return inventory}}$$

$$\text{RE} = \frac{\text{Value Recovered}}{\text{Resources used}}$$

v) Recovery Rate (RR)

RR = 1-(S/N)

Where, S is the number of items scrapped per unit time

BEST PRACTICE	
Presence of educational and training programs to employees	
Use of eco-friendly product and packaging materials	
Use of recycle materials to manufacture virgin products	
Promotion of industry wide cooperative efforts on environmental issues	
Support end-of-life processing by tracking product data from design through end-of-life	

N is the total number of items inducted into the asset recovery process

vi) Environmental Effectiveness (EE)

Environmental conformance effectiveness is an easy to use and implement qualitative measure that combines the best practices in environmental compliance, and ensures that the investments made in compliance initiatives are best leveraged

Table 4. Checklist for EE

BEST PRACTICE	
Real time updating of inventory in ware houses	
Application of RFID technologies for tracking stored return products	
Use of separate CRC's to handle returns	
Provision of special handling requirements	
Use of full time employees dedicated to handling returns	

vii) Overall Vehicle Effectiveness (VE)

It is also a qualitative measure.

Table 5. Checklist for VE

BEST PRACTICE	
Use of computer network technology to track return products from Gate-keeping to disposal	
Use of special bins for distinction between virgin and return products	
Use of automated systems for generating return goods authorization	
Provision of online web capability to schedule returns pickups	
Coordinate returns shipments to get lower transportation costs and improve vehicle and mileage utilization	

viii) Return Transit Time (RT)

$$\textbf{RT} = \frac{\textbf{T}}{\textbf{N}}$$

Where,
T is the total time spent by a product return in transit

N is the number of products entering the reverse supply chain

Step 13: Categorize the performance within the electronics industry in the form of scales to assign performance ratings at the measures

TRANSPORTATION (TN)			
VE		RT (mins)	
Range	**Rating**	**Value**	**Rating**
VE=5	1.00	40	1.00
VE=4	0.80	50	0.50
VE=3	0.60	60	0.00
VE=2	0.40		
VE=1	0.20		

Table 6. Performance Scale for GK

SORTING AND STORING (SS)			
WE		RC (%)	
Range	**Rating**	**Value**	**Rating**
WE=5	1.00	0	1.00
WE=4	0.80	2.5	0.50
WE=3	0.60	5	0.00
WE=2	0.40		
WE=1	0.20		

Table 7. Performance Scale for SS

ASSET RECOVERY					
RE (%)		RR (days)		EE	
Value	**Rating**	**Value**	**Rating**	**Range**	**Rating**
25	1.00	0	1.00	EE=5	1.00
12.5	0.50	0.35	0.50	EE=4	0.80
0	0.00	0.70	0.00	EE=3	0.60
				EE=2	0.40
				EE=1	0.20

Table 8. Performance Scale for AR

Table 9. Performance Scale for TN

GATE-KEEPING (GK)			
RV (Rs/day)		GE	
Value	**Rating**	**Range**	**Rating**
0	1.00	GE=5	1.00
12000	0.50	GE=4	0.80
24000	0.00	GE=3	0.60
		GE=2	0.40
		GE=1	0.20

Step 14: Calculate the performance score at the measure

Performance Score at the RL measure: $S_m = PR * W_m * W_f$

PR – Performance rating of the firm
W_m- Metrices weight
W_f – Functions weight

Step 15: Compute the reverse logistics performance value (RLPV) by summing up all the performance scores at the RL measures

Table 10. RLPV

	PR	W_m	W_f	S_m
GK				
RV				
GE				
SS				
WE				
RC				
AR				
RE				
RR				
EE				

TN				
VE				
RT				
RLPV				

Step 16: Stop

V. CASE ILLUSTRATION

The model presented in this paper has been evaluated in two information technology and telecommunication equipment industry A and B, which were interested in the implementation of the reverse logistics practices.

A. Metrices weight-Company A

GK	RV	GE	Weight
RV	0.10	0.10	0.10
GE	0.90	0.90	0.90

Table.11. Metrices weight for Gate keeping function

B. Functions weight- formation of super matrix-Company A

The pair wise comparison matrices for various strategies as mentioned in methodology is calculated.

Table 12 Pair-wise comparison matrix of relative importance of functions with respect to Gate-keeping function-*Company A*

GK	SS	AR	TN	Weight
SS	1	1/4	1/3	0.12
AR	4	1	2	0.56
TN	3	1/2	1	0.32

Table 13.Pair-wise comparison matrix to determine the effect of RL functions on each other under Customer Satisfaction strategy-*Company A*

CS	GK	SS	AR	TN	Weight
GK	1	9	6	7	0.65
SS	1/9	1	1	¼	0.07
AR	1/6	1	1	4	0.16
TN	1/7	4	1/4	1	0.12

Table 14.Pair-wise comparison matrix to determine the relative importance of strategies under Gate-keeping function-*Company A*

GK	CS	NT	RP	SA	KM	VR	Weight
CS	1	1/2	7	4	1/2	2	0.20
NT	2	1	5	4	½	3	0.26
RP	1/7	1/5	1	1	1/5	1/3	0.05
SA	¼	1/4	1	1	1/4	1/5	0.05
KM	2	2	5	4	1	2	0.30
VR	½	1/3	3	5	1/2	0.12	0.14

Table 15.Pair-wise comparison matrix to determine the relative importance of strategies under Introduction lifecycle stage-*Company A*

IN	CS	NT	RP	SA	KM	VR	Weight
CS	1	6	9	6	1	9	0.41
NT	1/6	1	4	2	1	4	0.15
RP	1/9	1/4	1	1/4	1/6	1	0.04
SA	1/6	1/2	4	1	1/3	6	0.11
KM	1	1	6	3	1	8	0.26
VR	1/9	1/4	1	1/6	1/8	1	0.03

Table 16.Pair-wise comparison matrix to determine the relative importance of lifecycle stages under Customer Satisfaction strategy-*Company A*

CS	IN	GR	MA	DE	OB	Weight
IN	1	1/5	1/3	7	8	0.18
GR	5	1	3	7	8	0.47
MA	3	1/3	1	6	7	0.25
DE	1/7	1/7	1/6	1	2	0.05
OB	1/8	1/8	1/7	1/2	1	0.04

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Table 17.Z-Vector to determine the total contribution of RL functions with respect to Customer Satisfaction strategy-*Company A*

GK	SS	AR	TN		CS		Z-Vector
1.00	0.68	0.67	0.2		0.65		0.83
0.12	1.00	0.27	0.31	*	0.07	=	0.23
0.56	0.26	1.00	0.49		0.16		0.60
0.32	0.06	0.06	1.00		0.12		0.34

Z-Vector value for GK function with respect to CS strategy = [(1*0.65) + (0.68*0.07) + (0.67*0.16) + (0.2*0.34)]

Table 18.Super matrix-*Company A*

	IN	GR	MA	DE	OB	CS
IN	0	0	0	0	0	0.18
GR	0	0	0	0	0	0.47
MA	0	0	0	0	0	0.25
DE	0	0	0	0	0	0.05
OB	0	0	0	0	0	0.04
CS	0.41	0.35	0.23	0.03	0.04	0
NT	0.15	0.06	0.03	0.03	0.04	0
RP	0.04	0.06	0.08	0.24	0.3	0
SA	0.11	0.09	0.05	0.12	0.06	0
KM	0.26	0.17	0.22	0.13	0.06	0
VR	0.03	0.27	0.38	0.45	0.49	0
GK	0	0	0	0	0	0.42
SS	0	0	0	0	0	0.12
AR	0	0	0	0	0	0.30
TN	0	0	0	0	0	0.17

Table 19.Column stochastic super matrix (M) -*Company A*

	IN	GR	MA	DE	OB	CS
IN	0	0	0	0	0	0.09
GR	0	0	0	0	0	0.24
MA	0	0	0	0	0	0.13
DE	0	0	0	0	0	0.03
OB	0	0	0	0	0	0.02
CS	0.41	0.35	0.23	0.03	0.04	0
NT	0.15	0.06	0.03	0.03	0.04	0
RP	0.04	0.06	0.08	0.24	0.3	0
SA	0.11	0.09	0.05	0.12	0.06	0
KM	0.26	0.17	0.22	0.13	0.06	0
VR	0.03	0.27	0.38	0.45	0.49	0
GK	0	0	0	0	0	0.21
SS	0	0	0	0	0	0.06
AR	0	0	0	0	0	0.15
TN	0	0	0	0	0	0.09

Table 20.Converged Super Matrix ($M^{2K+1} = M^{369}$) -*Company A*

	GK	SS	AR	TN
GK	0.42	0.42	0.42	0.42
SS	0.13	0.13	0.13	0.13
AR	0.31	0.31	0.31	0.31
TN	0.15	0.15	0.15	0.15

C. Metrices weight-Company B

GK	RV	GE	Weight
RV	1	9	0.90
GE	1/9	1	0.10

Table.21. Metrices weight for Gate keeping function

D. Functions weight- formation of super matrix-Company B

The pair wise comparison matrices for various strategies as mentioned in methodology is calculated.

Table 22 Pair-wise comparison matrix of relative importance of functions with respect to Gate-keeping function- *Company B*

GK	SS	AR	TN	Weight
SS	1	4	8	0.67
AR	1/4	1	7	0.27
TN	1/8	1/7	1	0.06

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Table 23.Pair-wise comparison matrix to determine the effect of RL functions on each other under Customer Satisfaction strategy- *Company B*

CS	GK	SS	AR	TN	Weight
GK	1	1/2	3	5	0.33
SS	2	1	1	5	0.35
AR	1/3	1	1	9	0.28
TN	1/5	1/5	1/9	1	0.05

Table 24.Pair-wise comparison matrix to determine the relative importance of strategies under Gate-keeping function- *Company B*

GK	CS	NT	RP	SA	KM	VR	Weight
CS	1	7	8	9	9	8	0.52
NT	1/7	1	6	7	6	7	0.25
RP	1/8	1/6	1	2	1/2	1	0.05
SA	1/9	1/7	1/2	1	2	1/2	0.05
KM	1/9	1/6	2	½	1	1/2	0.05
VR	1/8	1/7	1	2	3	1	0.07

Table 25.Pair-wise comparison matrix to determine the relative importance of strategies under Introduction lifecycle stage- *Company B*

IN	CS	NT	RP	SA	KM	VR	Weight
CS	1	3	8	4	8	9	0.44
NT	1/3	1	7	4	7	9	0.29
RP	1/8	1/7	1	1/5	1/2	1	0.04
SA	¼	1/4	5	1	4	6	0.15
KM	1/8	1/7	2	¼	1	2	0.05
VR	1/9	1/9	1	1/6	1/2	1	0.03

Table 26.Pair-wise comparison matrix to determine the relative importance of lifecycle stages under Customer Satisfaction strategy- *Company B*

CS	IN	GR	MA	DE	OB	Weight
IN	1	1/3	7	9	9	0.33
GR	3	1	8	9	9	0.51
MA	1/7	1/8	1	2	2	0.07
DE	1/9	1/9	1/2	1	2	0.05
OB	1/9	1/9	1/2	1/2	1	0.04

Table 27.Z-Vector to determine the total contribution of RL functions with respect to Customer Satisfaction strategy- *Company B*

GK	SS	AR	TN		CS		Z-Vector
1.00	0.68	0.67	0.2		0.65		0.83
0.12	1.00	0.27	0.31	*	0.07	=	0.23
0.56	0.26	1.00	0.49		0.16		0.60
0.32	0.06	0.06	1.00		0.12		0.34

Z-Vector value for GK function with respect to CS strategy = [(1*0.65) + (0.68*0.07) + (0.67*0.16) + (0.2*0.34)]

Table 28.Super matrix- *Company B*

	IN	GR	MA	DE	OB	CS
IN	0	0	0	0	0	0.33
GR	0	0	0	0	0	0.51
MA	0	0	0	0	0	0.07
DE	0	0	0	0	0	0.05
OB	0	0	0	0	0	0.04
CS	0.44	0.31	0.48	0.11	0.04	0
NT	0.29	0.05	0.22	0.2	0.47	0
RP	0.04	0.03	0.05	0.05	0.03	0
SA	0.15	0.43	0.07	0.22	0.23	0
KM	0.05	0.13	0.04	0.04	0.15	0
VR	0.03	0.04	0.15	0.37	0.07	0
GK	0	0	0	0	0	0.41
SS	0	0	0	0	0	0.32
AR	0	0	0	0	0	0.24
TN	0	0	0	0	0	0.06

Table 29.Column stochastic super matrix (M) - *Company B*

	IN	GR	MA	DE	OB	CS
IN	0	0	0	0	0	0.17
GR	0	0	0	0	0	0.26
MA	0	0	0	0	0	0.04

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DE	0	0	0	0	0	0.03
OB	0	0	0	0	0	0.02
CS	0.44	0.31	0.48	0.11	0.04	0
NT	0.29	0.05	0.22	0.2	0.47	0
RP	0.04	0.03	0.05	0.05	0.03	0
SA	0.15	0.43	0.07	0.22	0.23	0
KM	0.05	0.13	0.04	0.04	0.15	0
VR	0.03	0.04	0.15	0.37	0.07	0
GK	0	0	0	0	0	0.21
SS	0	0	0	0	0	0.16
AR	0	0	0	0	0	0.12
TN	0	0	0	0	0	0.03

Table 30.Converged Super Matrix ($M^{2K+1} = M^{49}$) - *Company B*

	GK	**SS**	**AR**	**TN**
GK	0.40	0.40	0.40	0.40
SS	0.31	0.31	0.31	0.31
AR	0.24	0.24	0.24	0.24
TN	0.09	0.09	0.09	0.09

E. Performance value of the firm

Return Value

For -*Company A*,

RV = n * N * C

Where,

n is the number of reverse logistic centre = 8

N is the number of return products in Gate-keeping per unit day = 10

C is the cost of a single returned product = Rs.150

Therefore, RV = 8 * 10 * 150

RV = Rs.12000/ day

For Company B,

RV = n * N * C

Where,

n is the number of reverse logistic centre = 10

N is the number of return products in Gate-keeping per unit day = 13

C is the cost of a single returned product = Rs.150

Therefore, RV = 10 * 13 * 150

RV = Rs.19500/ day

Table 31.Gate keeping Effectiveness (GE)

BEST PRACTICE	**A**	**B**
Clear and visible return policies to reduce the number of defective products into the RSC	✓	✓
Use of dedicated and skilled labour for return product inspection	✓	✓
Use of latest equipment for checking the reliability of the product	✓	✓
Use of multiple channels such as phone and internet to provide support		✓
Employ programs to reduce idle time of trucks and products at Gate Keeping	✓	✓

Checklist for evaluating performance rating of Gate-keeping Effectiveness

We have rated each parameter in the check list as 0.2 according to likert's scale.

Therefore, performance rating of GE in Company A = 4 * 0.2 = 0.8

Similarly performance rating of GE in Company B = 1.

F. Calculation of RLPV

Table 32. RLPV-Company A

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	Value	PR	W_m	W_f	S_m
GK				0.42	
RV	Rs.12000	0.50	0.10		0.021
GE	4	0.80	0.90		0.302
SS				0.13	
WE	3	1.00	0.90		0.117
RC	4%	0.00	0.10		0.000
AR				0.31	
RE	17.19%	0.50	0.17		0.026
RR	0.3 days	0.50	0.76		0.1178
EE	3	0.60	0.06		0.0111
TN				0.15	
VE	4	0.80	0.10		0.012
RT	51 mins	0.50	0.90		0.0675
RLPV					0.6744

Table 33. RLPV-Company B

	Value	PR	W_m	W_f	S_m
GK				0.40	
RV	Rs. 19500	0.00	0.90		0.000
GE	5	1.00	0.10		0.040
SS				0.31	
WE	4	0.80	0.90		0.2232
RC	4.2%	0.00	0.10		0.000
AR				0.24	
RE	21%	1.00	0.76		0.1824
RR	0.66 days	0.00	0.17		0.000
EE	4	0.80	0.06		0.048
TN				0.09	
VE	5	1.00	0.90		0.081
RT	42 mins	1.00	0.10		0.009
RLPV					0.5836

VI. CONCLUSION

The function weights along with the measure weights from the pairwise matrices and the performance ratings developed for each of the two case studies have been illustrated in table 32 and table 33. In addition, the actual performance metric values obtained from the interview process have also been included. Based on the formulations developed, the performance score of Company A was obtained to be 0.6744 or 67.44% and that of Company B to be 0.5836 or 58.36 % of the industry average standards. In the case of this research, it is important to note here that the data used is skewed and that these figures do not accurately represent the information technology and telecommunication equipment industry standards due to the fact that only two companies were used for data collection. Ideally, in order to validate the results, a bigger survey sample size is necessary.

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