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Selection of Influencing Factors on Reverse Logistics Management in Process Industries

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Abstract

This research investigates concerns on information and logistics management related by means of reverse logistics in the Indian Manufacturing Industries. The study analyzed the factors that influence reverse logistics in that domain. Concerns, including Value Recovery Operations, Return Policy, Reverse Logistics Service, Product Return Operations, Techniques, and Information Technology Enabling Services were tackled to set up reverse logistics' value in the industries. This study investigated Indian industries which includes process industries through questionnaire survey. The data collected from the survey was analyzed using regression analysis and Friedman Test to understand reverse logistics issues in the firms. Based on the literature and outcomes of the preliminary study, hypotheses were formulated to test their validity while establishing reverse logistics issues in Indian Process industries.

Keywords: Reverse Logistics Services (RLS), Return Policies (RL), Information Technology Enabled Services (ITES), Communication techniques (CT), Reverse Logistics Operations (RLO), Regression Analysis, Friedman Test, Dependent variables and Independent variables.

1. Introduction

Reverse logistics refers to the management of returned goods and encompasses the planning, implementation, and control of the movement of raw materials, finished products, and related information from the point of consumption back to the point of origin. This process

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is aimed at recapturing value or ensuring proper disposal, as defined by [1]. It plays a significant role in manufacturing organizations by supporting strategic marketing initiatives and enhancing effective customer relationship management [2,3]. Additionally, reverse logistics contributes to environmental conservation and sustainable development [4]. According to Bayles et al [5]it facilitates the reuse of returned products due to commercial returns and helps manage surplus inventory of materials and products. The process includes handling damaged goods, seasonal and surplus stock, restocking, salvaging, and recalling products [4] Key aspects of reverse logistics management include recycling programs, managing hazardous materials, disposing of obsolete equipment, and recovering assets. The advantages of reverse logistics include recapturing value, gaining a competitive edge [2] and making a positive environmental impact [4]

2. Research Methodology

Figure 1 illustrates the research methodology flow chart. The study focuses on managing reverse logistics, specifically within South Indian industries [8]. This literature review offers valuable insights to recognize and evaluate reverse logistics as a crucial business process. At the conclusion of the review, the research objectives, questions, and a conceptual process model for reverse logistics were formulated. A preliminary study was initially conducted with various industries to assess the current state of reverse logistics practices.

To gather data, a survey instrument in the form of a questionnaire was developed, drawing from previous research and existing literature. Inputs were also sought from experts, logistics researchers, and managers working in reverse logistics firms. The questionnaire covered several key areas, including the significance of logistics activities within organizations, reasons for outsourcing, the adoption of IT-enabled services (ITES) by reverse logistics firms, the influence of reverse logistics services on logistics performance, their impact on specific business operations, and the challenges and issues commonly faced by reverse logistics providers and their users [14].

A separate questionnaire was designed specifically for reverse logistics users. It comprised multiple sections, each focusing on a distinct theme. To ensure its robustness, three types of validity tests were applied:

Content Validity: Evaluating whether the questionnaire adequately covered all relevant aspects required to answer the research questions.

Criterion Validity: Measuring the correlation between the survey results and predetermined standards.

Construct Validity: Assessing whether the measurements aligned with theoretical claims.

An internal consistency test was performed to ensure the reliability of responses. A pilot study was conducted to evaluate the validity of the questionnaire. It was pre-tested for content, criterion, and internal consistency with six CEOs from logistics firms and three academicians specializing in supply chain operations. Their feedback was incorporated to refine the instrument.

Hypotheses were then developed to test their applicability across multiple industries [9]. Questionnaire surveys were conducted within the manufacturing, home appliances, and process industries. The collected data was analyzed to identify reverse logistics issues and validate the hypotheses in these sectors. The findings provided insights into reverse logistics challenges in manufacturing, home appliances, and process industries. This flow chart of research methodology shown in Figure 1 has been developed and generated with the consultation of academicians and industrial experts.

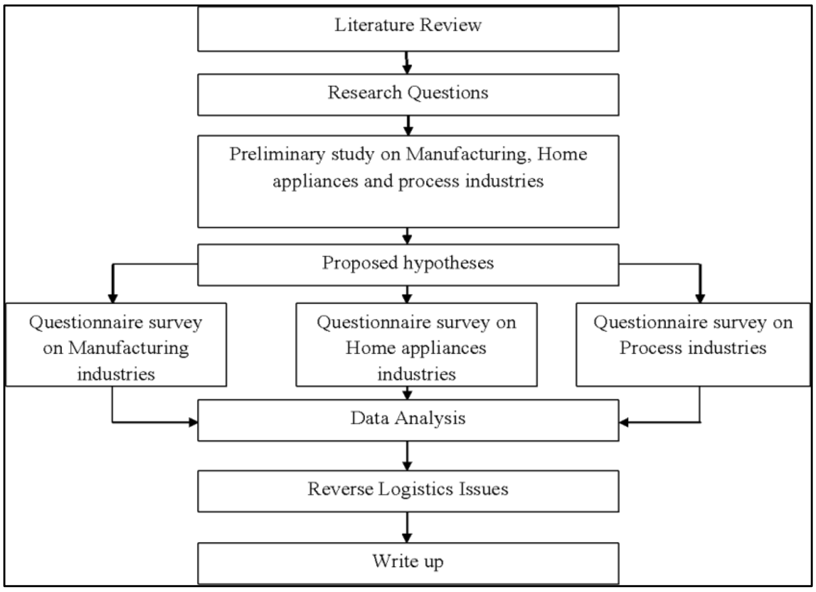

Figure 1. Flow Chart of Research Methodology

3. Scope of the Work

This study focuses on the management of reverse logistics within Indian industries. The reviewed literature offers comprehensive insights into identifying barriers and recognizing reverse logistics as an integral business process in industrial operations [12]. It establishes frameworks emphasizing that reverse logistics and service providers should be acknowledged as critical components of business processes in India [6].

This study presents an analysis of the data gathered from respondents across the manufacturing, home appliances, and process industries in South India [10]. A detailed discussion has been carried out to find the most influencing factor of Reverse Logistics Services (RLS) and Return policies (RP) among these industries using Regression Analysis. Friedman test is used to find out the most influencing sub-factors among Information Technology Enabled Services (ITES), Communication Techniques (CT) also termed Techniques. Reverse Logistics Operations (RLO) in these industries handle reverse logistics [13]. The details are provided under various subheadings.

Most of the South Indian industries using RLM are falling under the following three major categories:

Industries carry out manufacturing activities (Manufacturing Industries).

Industries involved in domestic appliance production and distribution activities (Home Appliances Industries).

Industries involving process engineering (Process Industries).

Before distributing the developed questionnaires among the South Indian industries, the size of the sample must be defined. Determination of sample size, when population size is not known can be carried on if population proportion is equal i.e., (0.5 known, 0.5 unknown). The formula used for sample size determination is given in equation stated below.

$$n = \frac{z^2\, p\, q}{e^2}$$

where ‘z’ is the confidence level value at 95% = 1.96

‘e’ is the ‘margin of error’ also known as ‘distance of assurance’

‘p’ is the ‘known population proportion’ and ‘q’ is the ‘unknown population proportion’

If ‘p’ is unknown, substitute the maximum value of p = 0.5. z^2 is 3.84 at 95% confidence level, so that sample size is calculated as 266.78. Studies conducted by Rogers & Tibben-Lembke et al. [1] showed that more than 2/3 of manufacturing companies use RLM as compared to home appliances and process industries. Therefore, under this study the questionnaires had been distributed to 160 manufacturing industries [10]. The Table.1 shows the distribution of questionnaires and the number of questionnaires filtered based on the accuracy of the respondent’s questionnaires.

3.1 Responses to the Questionnaire for RLM

Table 1. Distribution of Questionnaires

Category of Industry Surveyed	Questionnaire Distributed	Questionnaire Received	Questionnaire Filtered
Process Industries	160	147	93

3.2 Null Hypothesis

The following null hypotheses are framed for regression analysis:

- The three independent variables ITES, RLO, and CT equally influence the dependent variable RLS in Manufacturing Industries.
- The three independent variables ITES, RLO, and CT equally influence the dependent variable RP in Manufacturing Industries

4. Studies on Influencing Criteria using Regression Analysis

Multi-linear regression analysis is a quantitative research method employed to study relationships involving multiple variables [7]. This approach examines the connection between a dependent variable (Y) and several independent variables (X1, X2, X3, …). It is a linear methodology used to analyze the relationship between the identified factors of the scalar dependent variables, such as RLS and RP, and the independent variables, including ITES, CT, and RLO [11]. Initially, incomplete data were excluded, and the remaining data were coded and recorded for analysis.

The data analysis was conducted for manufacturing, home appliances, and process industries, considering all dependent and independent variables individually using Minitab software. The subsequent analysis is categorized into initial results and reverse logistics issues. The null hypothesis posits that the slope of the regression line is equal to zero, while the alternative hypothesis asserts that it is not equal to zero. The p-value for each term tests the null hypothesis, indicating whether the coefficient is zero (indicating no effect). The p-value ranges between 0 and 1, with a value less than 0.05 typically suggesting strong evidence against the null hypothesis, warranting its rejection.

Regression analysis (RA) was conducted for three categories of industries, with two specific cases for each, as detailed below:

RA (1): Analysis of the relationship between the dependent variable (Y) and independent variables (X1, X2, X3, …) in manufacturing industries.

Case (i): The dependent variable (Y) is RLS, and the independent variables are ITES (X1), CT (X2), and RLO (X3).

Case (ii): The dependent variable (Y) is RP, and the independent variables are ITES (X1), CT (X2), and RLO (X3).

4.1 Analysis of Relationship between Dependent and Independent Variables in Process Industries – RA (3)

The linear regression analysis is carried out between RLS and ITES, CT, RLO in case (i) RP and ITES, CT, RLO in case (ii). The details of the regression analysis are summarized in Table 2

Table 2. Regression Analysis

Case	S	R-Sq	R-Sq (adj)	R
Case (i)	0.0203159	0.9573	95.23%	0.9784
Case (ii)	0.0307885	0.8979	88.61 %	0.9475

In Case (i), the multiple correlation coefficient (0.9784) indicates the strength of the relationship between the actual values and the predicted values for the effectiveness of RLS. The predicted values, derived as a linear combination of ITES (X1), CT (X2), and RLO (X3), result in a coefficient value of 2.3890. This demonstrates a strong and positive association between RLS and the three independent variables.

In Case (ii), the multiple correlation coefficient (0.9475) reflects the degree of relationship between the actual values and the predicted values for the effectiveness of RP. Similarly, the predicted values, obtained as a linear combination of ITES (X1), CT (X2), and RLO (X3), yield a coefficient value of 2.4320. This confirms a robust and positive relationship between RP and the three independent variables. Analysis of Variance of RA (3): case (i) as shown in Table 3

Table 3. Analysis of Variance of RA (3): Case (i)

Source	DF	Adj SS	Adj Ms	F Value	P Value
Regression	3	0.240365	0.080122	194.12	0.000
ITES	1	0.001583	0.001583	3.84	0.061
Techniques	1	0.035167	0.035167	85.21	0.000
RLO	1.	0.039486	0.039486	95.67	0.000
Error	26	0.010731	0.000413	-	-
Lack of Fit	24	0.010728	0.000447	335.76	0.003
Pure Error	2	0.000003	0.000001		
Total	30	0.251096			

In both cases, the coefficient of determination, represented as R-square, assesses the goodness-of-fit of the sample regression plane (SRP) by examining the proportion of variation in the dependent variables explained by the fitted regression model. In Case (i), the R-square value is 0.9573, indicating that 95.73% of the variation in Reverse Logistics Services (RLS) is accounted for by the SRP, which incorporates ITES, CT, and RLO as independent variables. The R-square value is significant at the 0.05 level. In Case (ii), the R-square value is 0.8979, signifying that 89.79% of the variation in RP is explained by the SRP, which includes ITES, CT, and RLO as independent variables. This R-square value is also significant at the 0.05 level.

In Case (i), the R value is 0.9784, while the R-square value is 0.9573, demonstrating a positive relationship between RLS and the independent variables. This implies that an increase in the values of the independent variables results in an increase in RLS. The F-statistic, used to evaluate the significance of R-square, is 194.12, and it is significant since the p-value is <0.05. This result confirms that 95.73% of the variation in RLS is explained by the three independent variables. A significant F-statistic indicates that the independent variables effectively explain the variation in the dependent variable. Analysis of Variance for RA (3): case (ii) as shown in Table 4

Table 4. Analysis of Variance for RA (3): Case (ii)

Source	DF	Adj SS	Adj Ms	F Value	P Value
Regression	3	0.216792	0.072264	76.23	0.000
ITES	1	0.002211	0.002211	2.33	0.139
Techniques	1	0.036143	0.036143	38.13	0.000
RLO	1	0.029248	0.029248	30.85	0.000
Error	26	0.024646	0.000948		
Lack of Fit	24	0.022194	0.000925	0.75	0.716
Pure Error	2	0.002453	0.001226		
Total	30	0.241438			

In Case (ii), the R value is 0.9475, and the R-square value is 0.8979, indicating a positive association between RP and the independent variables. This implies that an increase in the values of the independent variables leads to an increase in RP. The F-statistic, which evaluates the significance of R-square, is 76.23 and is significant, as the p-value is <0.05. This result confirms that 89.79% of the variation in RP is explained by the three independent variables. A significant F-statistic indicates that the independent variables effectively account for the variation in the dependent variable. Regression Coefficients for RA (3) as shown in Table 5

Table 5. Regression Coefficients for RA (3)

Case	Term	Coefficient	SE Coefficient	T-Value	P-Value
Case (i) Y=RLS	Constant	2.3890	0.0523	45.64	0.000
	ITES (X1)	0.0184	0.0094	1.96	0.061
	CT (X2)	0.1624	0.0176	9.23	0.000
	RLO (X3)	0.1144	0.0117	9.78	0.000
Case (ii) Y=RP	Constant	2.4320	0.0793	30.66	0.000
	ITES (X1)	0.0218	0.0143	1.53	0.139
	CT (X2)	0.1647	0.0267	6.17	0.000
	RLO (X3)	0.0985	0.0177	5.55	0.000

For Case (i), the estimated regression model is

$$Y = 2.3890 + 0.0184\,X_1 + 0.1624\,X_2 + 0.1144\,X_3 \quad (4.6)$$

Here, Y = RLS; X_1 = ITES; X_2 = CT; X_3 = RLO

Table 2 shows that the p-values for CT and RLO are significant at a 95% confidence level (<0.05), whereas the p-value for ITES is not significant. This indicates that CT and RLO have an impact on RLS in the Process Industries. Furthermore, since the coefficient value for CT (0.1624) is higher than that of RLO (0.1144), it can be concluded that CT is the most influential factor affecting RLS in the Process Industries.

From the Equation (4.6) it can be inferred that if the value of CT increases by one unit, then the value of RLS will increase by 0.1624 units. In Case (ii), the estimated regression model is

$$Y = 2.4320 + 0.0218\,X_1 + 0.1647\,X_2 + 0.0985\,X_3 \quad (4.7)$$

Here, Y = RP; X_1 = ITES; X_2 = CT; X_3 = RLO

As shown in Table 3 the p-values for CT and RLO are significant at the 95% confidence level (<0.05), while the p-value for ITES is not significant. This indicates that CT and RLO have an impact on RP in the Process Industries. Since the coefficient value for CT (0.1647) is higher than that for RLO (0.0985), it can be concluded that CT is the most influential factor affecting RP in the Process Industries. From Equation (4.7), it can be inferred that for each one-unit increase in CT, RP will increase by 0.1647 units. In both cases presented in Table 4, not all three independent variables have the same level of influence on the dependent variable. If the calculated value is <0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted. Therefore, the null hypotheses (5) and (6) are rejected, and the alternative hypotheses are accepted. The results of the linear regression for Case (i) and Case (ii) are visually represented in Figures 2 and 3 in process industries.

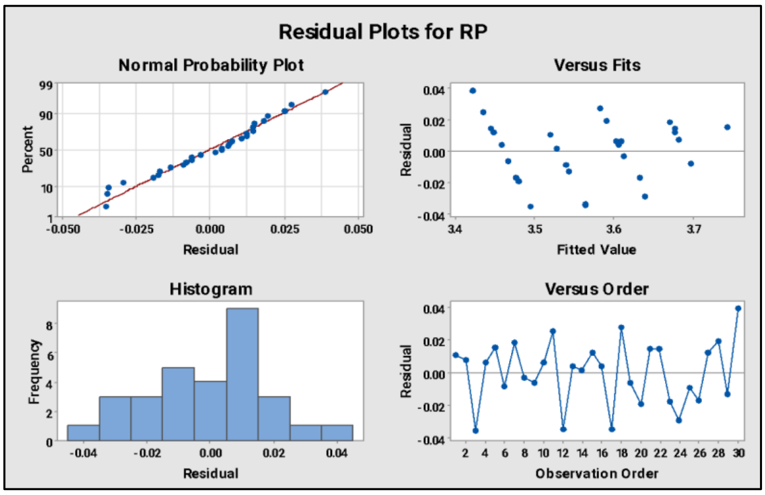

Figure 2. Analysis Results of RLS Versus Independent Variables of Process Industries

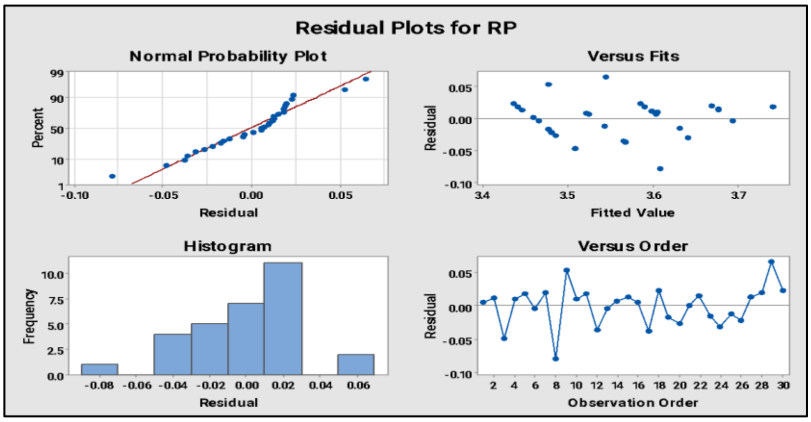

Figure 3. Analysis Results of RP Versus Independent Variables of Process Industries

4.2 Friedman's Test Analysis

To determine the sub-factor that has the greatest influence on 'CT' in process industries, the Friedman's test analysis was performed. This test is a non-parametric alternative used to examine differences between groups when the dependent variable is ordinal. It can also be applied to continuous data that exhibits deviations from normality. The Friedman test requires the following assumptions to be met:

- A single unit is evaluated under three or more different conditions.
- The unit represents a random sample from the population.
- The dependent variable must be measured at either an ordinal or continuous level.
- The sample data may not necessarily follow a normal distribution.

Identification of highly influencing sub factor in process industries are given below. From Friedman's test statistics (Source: Computed Data) of CT in process Industries, the following observations are noted.

N value is 93, Chi-Square (Friedman's Q) is 104.289

Degrees of freedom (df) is 6, Significance level is 0.000

From Friedman's test statistics (Source: Computed Data) of CT in Process Industries, the following observations are noted.

N value is 30

Chi-Square (Friedman's Q) is 53.765

Degrees of freedom (df) is 10

Significance level is 0.000

It could be noted from the above observation that among the eleven sub-factors of CT, "Computers / Desktop / Laptop" was ranked first. It is followed by the "Landline / Telephone / Fax" and "Internet'' was ranked third. The least important variable is "Electronic Data Interchange".

The Friedman test statistic, denoted as Friedman Q, measures the variance of the mean ranks. It equals 0 when the mean ranks are identical and increases as the mean ranks diverge. According to Table 6, the Friedman test shows that the technology variables (CT) are rated differently, with a Friedman Q value of 53.765, which is highly significant (p = 0.000). Figure 4 shows the Ranking of CT Variables

Table 6. Frequency Distribution of CT Variables (sub-factors**)**

Variables of CT	Extremely Low Use	Low Use	Use	High Use	Extremely High Use
Landline Telephone / Fax	0	0	5	12	13
Computers / Desktop Laptop	0	0	3	4	23
Electronic Data Interchange - EDI	11	5	1	9	4
Barcode Technology	13	0	0	8	9
Decision Support System	5	4	6	9	6
Data Logging	9	3	2	10	6
Track & Tracing Technological Systems	6	3	8	5	8
Global Positioning Systems / Geographical Information System	7	5	2	7	9
Entrepreneurship Resource Planning	3	0	10	10	7
Intranet	6	3	10	9	2
Internet	0	2	9	8	11

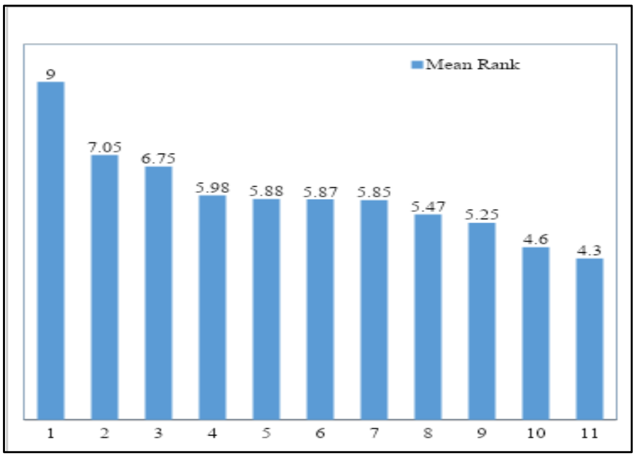

Figure 4. Ranking of CT Variables

4.3 Discussion

Process Industry

From the analysis in process industries, it is concluded that the independent variable CT (0.1624) is the predominant factor which is highly influencing the dependent variable RLS. It is followed by the next dominant factor RLO (0.1144) which influences RLS. From the results obtained, it can be concluded that if CT services offered by process industries increases by one unit, then RLS increases by 0.1624 units. So, the alternate hypothesis is accepted.

5. Conclusion

From the analysis in process industries, it is concluded that the independent variable CT (0.1647) is the predominant factor which is highly influencing the dependent variable RP. It is followed by the next dominant factor RLO (0.0985) which influences RP. From the results obtained, it can be concluded that if CT services offered by process industries increases by one unit then RP increases by 0.1647 units. So, the alternate hypothesis is accepted.It is concluded that CT is the predominant factor influencing both RLS and RP in Process Industries. The CT is formulated with eleven sub-factors. From the Friedman's test statistics of CT, the sub factor – Computer / Desktop/ Laptops ranked first as it highly influences CT. It is followed by the sub-factor Landline / Telephone / Fax and Internet respectively. The future research can be targeted in the following ways: It is construed that the proposed generic taxonomy components framework can be adopted by any company in the RL business either directly in its present form or with incorporation of suitable changes according to their context and priorities. The practical issues concerned with the implementation of the framework systems in RL business as well as its influence on business outcomes are to be explored. The investigation of this work can be extended to shipping and aerospace industries.

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