Improving Green Computing in Business Intelligence by Measuring Performance of Reverse Supply Chains

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Abstract— **Increasing attention has been given to green computing in Business Intelligence. This paper specifically considers the measurement of performance in the reverse supply chain. That is because of the increasing value of products and technology at the end of general direct supply chains as well as the impact of new green legislation. Unlike forward supply chains, design strategies for reverse supply chains are relatively unexplored and underdeveloped. Meanwhile measuring supply chain performance is becoming important as the need for data in business intelligence systems increases and the understanding, collaboration and integration increases between supply chain members. It also helps companies to target the most profitable market segments or identify a suitable service definition. This paper describes a synthesis of known theory concerning measuring performance and assesses the state of the art. Strengths and gaps are identified. Some initial results are presented for measuring supply performance in reverse supply chains (*using robust methods*) and are outlined future research needs.**

Keywords; reverse supply chain; busness performance measurement

I. Introduction

Campbell [1] identified green computing as a top trend in Business Intelligence (BI). Green computing refers to environmentally sustainable computing. Murugesan [2] defined green computing as the study and practice of designing, manufacturing, using, and disposing of computer equipment (monitors, printers, storage devices and communications systems) efficiently and effectively with minimal or no impact on the environment. This paper describes potential improvement of green computing in BI by considering the measurement of performance in reverse supply chains because a goal of green computing is to maximize energy efficiency during a product's lifetime, and promote the recyclability of defunct products.

Reverse supply chains deal with the backward flow of products recovered from users. This happens for many reasons such as: the rise of electronic retailing; the increase in catalogue purchases; more self-service stores; or a lower tolerance among buyers for imperfection. Increasing attention has been given to the reverse supply chain (RSC) due to the increasing value of products and technology at the end of general direct supply chains as well as the impact of green legislation. These products, parts, subassemblies, and materials represent rapidly growing values and economic opportunities at the end of the direct supply chain [3]. The increased financial return provides the tangible benefit that Kimball [4] stated was required for BI systems.

Product returns are also becoming a concern for many manufacturers. For most companies, product returns have been viewed as a nuisance; as a result, their legacy today is a reverse supply chain designed to minimize cost. Few companies are dealing with it properly[5].

Unlike forward supply chains, design strategies for reverse supply chains are relatively unexplored and underdeveloped. However, product returns and their reverse supply chains represent an opportunity to create a value stream, not an automatic loss. Therefore, reverse supply chains should be managed as business processes that can create value for a company.

According to Stock [6] in reverse supply chains, it is important to develop and implement measurement systems to track the performance. Rostandas states performance measurement has a far more significant role than just quantification and accounting. It provides management with feedback to monitor performance, reveal progress and diagnose problems [7]. In addition, it is also making contribution to decision making, particularly in re-designing business goals and strategies and re-engineering processes[8].

Performance measurement for RSC has been mentioned as important in some literature but there is lack of knowledge about this area. Therefore, this paper:

1. Makes a synthesis of what has been published on measuring performance for RSC and thereby assesses the state of the art in the field.
2. Analyses strengths and what is needed.

The paper ends with a discussion and outlines future research needs.

II. Literature Review

A literature review identified articles within the field of reverse supply chains (RSC) and performance measurement (PM). The review used three data bases and several key words as seen in Table I.

TABLE I. Number of results in literature review

Database/ Key words	Engineering Village	IEEEXplore	Science Direct
RSC	741	296	605
RSC and Performance	192	38	429
RSC and PM	43	2	163

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Using science direct, 163 articles and books are found. However, most did not address the correct subject. The term supply chain led to many articles that focused on supply chains and not reverse supply chains. Finally a number of key articles were identified that fulfilled the criteria. These are presented in Table II.

TABLE II. RELEVANT ARTICLES IN THE LITERATURE

Year	Authors	Title
2012	Bjorklund, Maria [9]	Performance measurements in the greening of supply chains
2011	Olugu, E.U. [10]	Development of key performance measures for the automobile green supply chain
2009	Pochampally, K.K.[11]	Metrics for performance measurement of a reverse/closed-loop supply chain
2009	Kannan, G.[12]	A metaheuristics-based decision support system for the performance measurement of RSC management
2008	Hong, J.Y.[13]	Identifying the factors influencing the performance of RSC
2008	Tonanont, Ake [14]	Performance evaluation in reverse logistics with data envelopment analysis
2007	Rajagopalan, Santhanam [15]	Development of methodology for measuring and reducing value recovery time of returns
2004	Kongar, Elif [16]	Performance measurement for supply chain management and evaluation criteria determination for RSC management
2005	Hervani, A.A[17]	Performance measurement for green supply chain management
2007	Tian, Zu-hai [18]	Study on Choosing Reverse Logistics Operating Modes of Enterprises-Based on AHP Method
2011	Shaharudin, M.R [19]	Sustainable services in Closed Loop Supply Chains (CLSCs)
2010	Tu, C.C.[20]	Study of the performance of reverse logistics for supply chain management
2010	Xiao-le, Zhang [21]	Interrelationship between uncertainty and performance within reverse logistics operations
2004	Pochampally, Kishore K. [22]	Efficient Design and Effective Marketing of a Reverse Supply Chain: A Fuzzy Logic Approach

Kongar indicated that reverse supply chain management demanded an appropriate evaluation approach as it differed from forward supply chain management in many aspects [16]. Performance measurement for green supply chain management (GSCM) was introduced by Hervani *et al* in 2005 [17]. Meanwhile, Guide and Wassenhove [23] mentioned performance measurement as an important issue in a roadmap for redesigning reverse supply chains.

In the next section, reverse supply chains are discussed. It includes definitions of reverse supply chain and closed loop supply chain and link the subject to the activities and players involved. Performance measurement of forward supply chains is discussed. Definitions and the importance of performance measurement is explored. This section also presents a review of a previous conceptual performance measurement framework in a supply chain. The categorisation of individual performance and performance measurement at various hierarchical levels are addressed.

A. Reverse Supply Chain

A reverse supply chain (RSC) is a series of activities required to retrieve a used or unused product from a customer and either dispose of it, reuse it, or resell it [24].

At the end of every RSC, companies have an option to close or leave it open. Leave it open means the products in a reverse supply chain will go to different destinations from the original supply chain. For example they might be sold to brokers, donated to charities or sent to landfills. Supply chains could also be made by creating a loop. This closed loop supply chain consists of a reverse supply chain and an extra loop to connect it to the original forward supply chain [3]. Guide and van Wassenhove stated that the companies that have been most successful with their RSC are those that closely coordinate them with their forward supply chain, creating a closed-loop system [23].

To make rational decisions about the structure of a reverse supply chain, Guide and van Wassenhove [24] declared it is best to divide the chain into five key components and analyse options, costs and benefits for each:

- Product acquisition:

  To obtains products from end-users. Retrieving the used product is key to creating a profitable chain. At this stage it is important to manage the quality, quantity and timing of product returns.

- Reverse logistics:

  To move products from the points of use to a point(s) of disposition. There is no one 'best' design for a reverse logistics network; each has to be personalised to the product involved and the economics of its reuse.

- Inspection and disposition:

  The testing, sorting and grading of returned products are labour-intensive and time consuming tasks. In general, a business should seek to make disposition decisions - based on quality, product configuration, or other variance - at the earliest possible stage in the return process.

- Remanufacturing or Reconditioning:

  Companies may capture value from returned products by extracting and reconditioning components for reuse or by completely remanufacturing for resale.

- Remarketing:

  To create and exploit markets for refurbished goods and distribute them. If companies plan to sell recycled products, it first needs to determine whether there is a demand for them or whether new market must be created.

To understand the whole concept of RSC, the characteristics have to be investigated. The characteristics are illustrated in Figure 1.

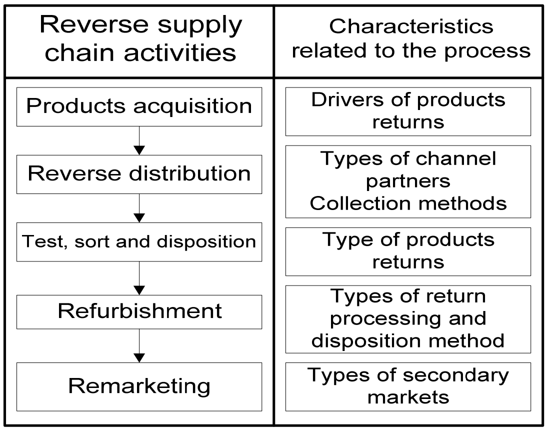

Figure 1. Characteristic of RSC [24]

A driver of product return is the reason that products are flowing back from end customers. Users may return products for different reasons at different stages in the product lifecycle[23]. Numerous classification of product returns have been given by several authors in the past according to different categories as seen on Table III.

TABLE III. CLASSIFICATION OF PRODUCT RETURNS

Authors	Categories of Product Returns
Rogers and Tibben-Lembke [25]	Reverse flow of products Reverse flow of packaging
De Brito and Dekker [26]	Manufacturing phase Distribution phase Customer use returns

One factor in achieving an effective reverse supply chain is an efficient establishment of schedules, transportation and networks [27]. Fleischmann *et al* described a network model for a recovery network there are three facilities involved [28]:

- disassembly centres which house inspection and separation activities
- factories for reprocessing and/or new production
- distribution warehouse to keep inventory of unprocessed and processed returns.

Although the reverse supply chain could include the same channel participants as the forward supply chain, usually the reverse flows are either supplemented or entirely supported by alternative channel participants[29].

In reverse supply chains, there are additional processes compared with forward supply chains. The processes are dependent on the condition (quality) of returns and appropriate channels are chosen based on recovery options[30].

Thierry *et al* [31] presented a category of product recovery options where each of them implied collection of used products and components, reprocessing and redistribution. The only thing that was different involved reprocessing activities. There were five main activities: repairing; refurbishing; remanufacturing; cannibalisation (in the context of component reuse) and recycling.

TABLE IV. COMPARISON BETWEEN PRODUCT RECOVERY OPTIONS [31]

	Level of Disassembly	Quality Requirements	Resulting Product
Repair	To product level	Restore product to working order	Some parts fixed or replaced by spares
Refurbishing	To module level	Inspect all critical modules and upgrades to specified quality level	Some modules repaired/replaced; potential upgrade
Remanufacture	To part level	Inspect all modules and parts and upgrade as new quality	Used and new modules/parts combined into new products; potential upgrade
Cannibalising	Selective retrieval of parts	Depends on process in which parts are reused	Some parts reused; remaining products recycled/disposed
Recycling	To material level	High for production of original parts; less for other parts	Material reused to produce new parts

Repairs were done to return used products to "working order" by fixing or replacing broken parts. Refurbishing required replacement of critical modules if needed. Remanufacturing transformed products to 'new' quality standards disassembly and extensive inspection. Cannibalisation involved work to salvage parts to be reused in repair, refurbishing, or remanufacturing of other products and components. The process in which they will be reused determined the quality standards of cannibalised parts. Recycling required disassembly of parts where they were separated to acquire the distinct materials. In this process, the original physical and functional structures are not retained. Table IV presented the main characteristics of the recovery process as well as the differences between them.

The last key component is remarketing. If the products return fulfills the quality standard, they will be restocked and sold at premium price. If the quality of products is lower, they will probably be sold at a lower price or in clearance shops.

B. *Performance Measurement (PM)*

Business Intelligence (BI) uses technologies, processes, and applications to analyze mostly internal, structured data and business processes. That needs performance measurement and Forrester refers to that sort of data preparation as a segment of the business intelligence architectural stack [32]. Performance measurement is often discussed but rarely defined. Neely *et al* describe performance measurement as the process of quantifying action, where measurement is the process of quantification and action correlates with performance. They also propose that performance should be defined as the efficiency and effectiveness of action [33].

There are many reasons why companies measure their performance. BI take all its capabilities and converts them into knowledge, ultimately, getting the right information to the right people, at the right time, to make a decision. BI can lead to the development of new opportunities for the organization. When these opportunities have been identified and a strategy has been effectively implemented, then they can provide an organization with a competitive advantage in the market [2]. In order for BI to support better business decision-making, measurement and data capture is necessary. Cuthbertson and Piotrowicz [34] mention measuring supply chain performance to increase understanding, collaboration and integration between supply chain members. It also helps companies to target profitable market segments or identify a suitable service definition. Furthermore, performance measurement is an activity to reach predefined goals derived from company's strategy objectives[35].

TABLE V. TYPICAL INDIVIDUAL PERFORMANCE MEASUREMENT [36]

Performance objective	**Some typical performance measures**	**Performance criteria that link firm strategy to operations decisions**
Quality	Number of defects per unit. Level of customer complaints. Scrap level. Warranty claims. Mean time between failures.	% defect reduction. % scrap value reduction. % unscheduled downtime reduction. % supplier reduction. % of inspection operations eliminated.
Speed or innovation	Customer query time. Order lead time. Frequency of delivery. Actual versus theoretical throughput time. Cycle time.	% increase in annual investment in new product and process research and design. % reduction in material travel time between work centres. % increase in annual number of new products introduction. % increase in common parts per products.
Dependability	Percentage of orders delivered. Average lateness of orders. Proportion of products in stock. Schedule adherence.	% reduction in purchased lead time. % reduction in lead time per product line. % increase in portion of delivery promises met.
Flexibility	Variance against budget.	% inventory turnover increase. % reduction of employee turnover. % improvement in labour/desired labour. % reduction in total number of data transactions per product. % average set-up time improvement per product line.

There are a large number of performance measures discussed in the literature. In the earlier literature, performance measures were usually divided into cost-related and non-cost-related performance measures. Stock [37] classified a group of individual performance measures based on the terms of the five manufacturing performance objectives: quality; speed; dependability; flexibility and cost. In Table V, examples of different performance measures are listed under these five categories.

There is a clear link between performance measures at all hierarchical levels, so that each function in a company works towards the same objectives. Flapper *et al* [38] clearly state, to have a strategic performance measure without related tactical and operational measures is not appropriate. In other words, it is important that a performance measure can be divided and correlated between these three levels: strategic, tactical and operational. Therefore, in order to derive the maximum benefit from reverse supply chain operations, a company should monitor its reverse supply chain through a performance measurement system that gives true results, according to the characteristics of return types and the nature of its reverse supply chain network.

III. RESULTS

From previous page, figure 2 shown the classification that presented to address systematically the products returned at each process stage along the supply chain process.

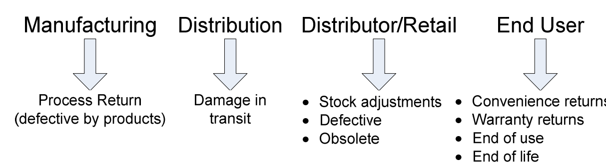

Figure 2. Types of Product Return

A. Performance Measurement in Reverse Supply Chain

Based on a wider survey of case studies in the field of reverse logistics, de Brito *et al* [39] claim that there is no broad knowledge on the costs associated with reverse logistics processes. In 2004, Herold and Kamarainen [40] emphasised that no previous studies were found about different performance metrics for reverse supply chains (RSC). This is shown, even though performance measurement for RSC has been mentioned as an important research area.

Nukala and Gupta [41] state that, traditionally performance measurement is defined as the process of quantifying the effectiveness and efficiency of action. Developing performance measurement systems is a difficult aspect of performance measure selection. Due to inherent differences between forward and the reverse supply chains, performance metrics and evaluation techniques used in traditional supply chains cannot be extended to reverse supply chains. Rogers *et al*[42] mention metrics briefly in their returns management process and emphasise the importance of measuring performance. They suggest return rates and financial impact of returns as appropriate measurements. Results show that evaluation of returned products is important and as it could impact on profitability.

Several papers propose important performance metrics to be used in certain circumstances. Blackburn *et al* [5] demonstrate how they apply key concepts from forward supply chain design - coordination, postponement, and the bullwhip effect and make a modification to the concept of product postponement. Rupnow [43] highlights the importance of performance measurements to benchmark and monitor returns by looking at the best practices at several leading companies such as Nintendo, US Robotics, Mitsubishi, Philips and Microsoft Xbox. A list of key goals and metrics is identified in helping these leading companies to succeed: reduce overall returns; reduce cost to process returns; increase recovery; reduce inventory; reduce turn-around time and increase customer satisfaction. Pochampally [11] did investigate some metrics but only at a strategic level.

Besides academics, practitioners also realise the importance of performance measurement in a reverse and closed-loop supply chain. The use of appropriate strategies and metrics allow a reverse supply chain to play a part in product and customer life-cycle strategies, and can serve as a foundation for identifying customer loyalties and increasing market share[27].

RSC has not been investigated at company level and this is identified as a gap in the research.

B. Robust Method

Robustness has a broad meaning and is often couched in different settings. Generally, robustness means that systems perform well when exposed to uncertain future conditions and perturbations [44]. In order to study supply chain robustness, an informative and effective performance measure is first required. Beamon [45] reviewed the supply chain literature and suggested directions for research on supply chain performance measures, which should include efficient resource allocation, output maximisation, and flexible adaptation to environmental changes. Different supply performance measures can be devised based on the specific nature of the problem.

One of the objectives in developing performance measures for closed-loop supply chains is to control the process along the traditional and reverse supply chains to adapt the common issues of product returns handling. The most recognized problem with handling product returns is the uncertainty of the incoming returns flow which relates to quality, quantity and timing[24]. In recovery networks, uncertainty in terms of returns' timing and quantity may result in inconsistency between the supply and demand. It is also difficult to predict the level of quality and availability of returns received which highlights the importance of separation and inspection as part of the recovery process[46]. Therefore, this issue makes supply uncertainty a characteristic in a recovery network. Product diversity is also a source of uncertainty[47]. The robust method has never been used in RSC.

C. Research gap

Although reverse supply chain and performance measurement have been discussed widely in the literature, performance measurement in reverse supply chains needs further investigation. In most literature, case studies only consider specific purpose with specific performance metrics to address a particular issue. Therefore, a performance measurement able to address all issues should be explored. This will involve using a number of performance metrics, which can be adopted from forward supply chain performance measurement, or specific metrics applied exclusively to reverse supply chains.

Uncertainty, disruptions, and variability are challenges in manufacturing systems and supply chains as well as reverse supply chains. The design and operation of such systems has to incorporate uncertainty about the future. Adaptability and flexibility are desirable features, as are robust design and plans. It is important to treat measurement systems as dynamic entities that respond to environmental and strategic changes. Therefore, measuring the performance of reverse supply chains will be investigated. A statistical study will be conducted to improve the usefulness of the proposed methods.

Based on the research gap, the framework in figure 3 is proposed. This framework aims to understand the performance measurement in a reverse supply chain.

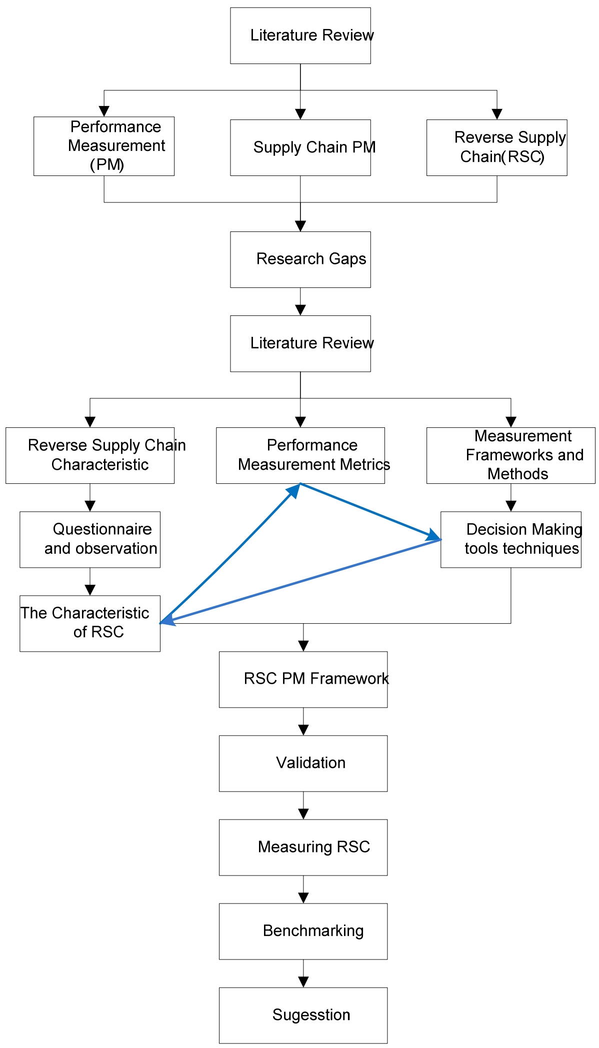

Figure 3. Research Process Overview

IV. Discussion and Conclusions

The first step was to understand reverse supply chains and performance measurement. Research gaps have been identified. Acquisition and synthesis of knowledge involved; reverse supply chain, performance measurement and forward supply chain performance measurement.

A second stage of the research was a theory development phase to find previous research about performance measurement and link it with reverse supply chain characteristics. This phase is ongoing and will cover the process of finding the characteristics of performance measurement and appropriate dimensions of performance. The theory will be used in developing a conceptual framework to link to strategic objectives in handling product returns to recovery networks.

That framework model will provide decision makers with a formal and systematic approach to selecting strategic objectives and towards using of meaningful performance attributes and performance metrics. To make sure research achieves a reliable result, validation will take place in the final stage. The new system will offer a practical approach to perform and manage the reverse supply chain more effectively.

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