DESIGN A REVERSE LOGISTICS INFORMATION SYSTEM WITH RFID

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Abstract: Recently, reverse logistics management has become an integral part of the business cycle. This is mainly due to the need to be environmental friendly and urgent need to reuse scarce resources. Traditionally, reverse logistics activities have been a cost center for most businesses without generating extra revenue. However, due to recent increase in commodity and energy prices, reverse logistics management could eventually be a cost savings method. In this research, we propose using Radio Frequency Identification (RFID) technology to better optimize and streamline reverse logistics operations. Using RFID, we try to eliminate parts of the unknowns in reverse logistics flow that made reverse logistics model complicated. Furthermore, Genetic algorithm is used to optimize the place of initial collection center so as to cover the largest population possible in order to reduce logistics cost and provide convenience to end users. This study is based largely on literature review of past workings and also experiments are conducted on RFID hardware to test for its suitability. The significance of this paper is to adopt ubiquitous RFID technology and Genetic Algorithms for reverse logistics so as to obtain an economic reverse logistics network.

1 INTRODUCTION

Reverse Logistics is the management of the return flow of materials from end users back to the producers. The management for reverse logistics is the opposite of conventional supply chain flow. Recently, reverse logistics management came into focus in an effort to cut cost. As of 1999, total value of merchandise returned in the U.S amounted to $62 billion. This represents a loss of around $10 -$15 billion to retailers while the cost of handling returned products was estimated to be $40 billion (ReturnBuy, 2000). However, the management of reverse logistics is complicated due to the many unknowns in the system and integration of reverse logistics to the forward logistics also proves to be a challenge (Fleischmann et al., 1997). This paper aims to overcome the uncertainties in reverse logistics process using wireless technology such as Radio Frequency Identification (RFID) to enable the dissemination of product information in real time. Genetic Algorithm (GA) is widely used in various aspects in supply chain to find out the optimized solution (Min et al., 2003). In this paper, GA is employed to determine the optimum location to deploy the various initial collection centers to develop an optimum reverse logistics network linking initial collection point and centralized return centers.

2 RELEVANT LITERATURE

2.1 Reverse Logistics

Reverse logistics is a field of interest with many recent studies conducted and models developed. Many models have been developed with regards to reverse logistics management with Barros et al. presenting a network for recycling of sands (Fleischmann et al., 1997). In his model, he proposed a multi-level capacitated warehouse model while using scenario analysis to solve for the uncertainties in the return flow. Spengler et al. on the other hand developed a mixed-integer linear programming model for recycling of industrial waste (Fleischmann et al., 1997) based on a multi-level capacitated warehouse location. At present, not many studies have been done to formulate a model integrating forward and reverse logistics process. Most of the models currently are planned based on forward logistics purposes. Min et al. (Min et al., 2003) developed a decision support system to

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support the design of distribution and collection networks. By using the location of the facility, the system can determine the optimal good flows in the return network and the resulting costs (Fleischmann et al., 1997). From these literature reviews, it is shown that reverse logistics process is not necessarily the opposite of forward logistics. Reverse logistics is more complicated in a sense that there are different actors involved and the uncertainties in the system are higher. This has not been addressed by most of the models at present and hence we will try to solve this in this research.

2.2 Radio Frequency Identification (RFID)

Radio Frequency identification (RFID) has been invented long ago but only recently has the technology emerge in mainstream applications. RFID is mainly used to tag products for identification purposes much like bar-code system today. However, RFID offers value-added advantage in that RFID does not need line-of-sight for operation and can read multiple tags at the same time, which has been a constraint for bar-code technology (Want, 2007). Much research is being done at the moment to search for application usage of RFID with recent adopters being US retail giant Wal-mart and Tesco. Although RFID promises a lot of advantages, there are also constraints and concerns about the technology. Most importantly is the additional cost needed to implement RFID technology to the current system because at the time being, RFID hardware is still costly. Secondarily, there is also a concern on the reliability of RFID technology and finally concern for privacy (Hunt, 2007). At the time being, not many studies have been done to integrate RFID technology to reverse logistics management system and this is an area where we will try to explore.

2.3 Genetic Algorithm

Genetic Algorithm (GA) is a form of mathematical optimization technique. GA can be used in various applications such as determining the optimum flow for a factory production process, optimum traveling route to determination of location of warehouses.

As compared to traditional optimization techniques, genetic algorithm is more robust due to the following features:

- Genetic algorithm works with a set of parameter and not the parameter itself. This lends to the robustness of genetic algorithm.
- Genetic algorithm search from a solution space and not a single point. Hence, genetic algorithm method does not depend on the existence of derivatives like traditional optimization techniques do.
- Genetic algorithm uses an objective function to determine the score of a chromosome and not based on derivatives or other auxiliary knowledge.
- Genetic algorithm uses probabilistic transition rules. This means that genetic algorithm selects strings to be included in the next stage or process based on probability whereby chromosomes with higher score are assigned a higher probability to be selected. This is the basis of survival of the fittest law.

All these advantages of genetic algorithm make it more robust and useful as compared to other traditional methods.

3 PROBLEM DEFINITION

As stated earlier, reverse logistics management is complex and involves a huge amount of unknowns. In-depth study has been done in this field and mathematical models have been developed to enhance the efficiency of reverse logistics. However, there are still limitations due to the following reasons:

1. Reverse distribution network is full of uncertainties such as the quantity and quality of the returned products from end users.
2. Different actors involved in the reverse distribution channel require different inventory control mechanism.
3. Forms of reuse differ for each product requiring different planning and coordination.
4. Difficulties in inventory control in systems with return flow.

Furthermore, there are also problems associated with integrating reverse flow of material into forward logistics due to:

1. Reverse distribution is not necessarily symmetric picture of forward distribution.
2. Special characteristics of reverse logistics include:
   - Many-to-few network structure
   - System uncertainties
3. Returned products may be sent to original producer or to third party recycling centre. Hence, further uncertainties and unknowns are involved.

4. Modification and extension may be necessary to tailor for reverse distribution.

For illustrative purposes, let us suppose that a computer manufacturer (called Apple hereafter) selling hardware to end-users intends to recycle used computers from its customers. Customers who wish to return the computer will dispose their computer at the various initial collection points and Apple will employ logistics providers to collect the disposed computer from the initial collection points.

Given the limited space at the initial collection points, returned products should be collected and shipped to the centralized collection centre as soon as possible and the components collected should be determined as soon as the returned products reaches the centralized collection center.

At the centralized collection center, components that can be reused may be redistributed after minor cleaning or refurbishing while defective components will undergo recycling processes. With the above situation as a model, we wish to address the following issues:

1. Location of initial collection point such as to cover the largest possible population in an area.
2. Location of centralized collection center such that transportation from initial collection point to the centralized collection center is minimum.
3. Method to obtain component information most efficient and timely from the returned product to determine for its quantity and quality.

4 MODEL DESIGN

4.1 Framework of Reverse Logistics

Reverse logistics is the management of material flow opposite to the conventional supply chain flow (Fleischmann et al., 1997). It encompasses logistic activities to transform used products from end users back to usable products again.

Reverse logistics management involves 3 main stages:

1. Distribution planning aspects – This stage involves physical transportation of used products from end users back to the producers.
2. Transformation – The recovery of returned product back to usable product. There are several ways of transformation including: Direct reuse, Repair, Recycling and Remanufacturing.
3. Inventory Management – This is to manage inventory level and to integrate supply flow from both the traditional supply chain and also from reverse logistics (Fleischmann et al., 1997).

Dimensions of Reverse Logistics. There are many instances of reuse criteria. These can be classified as motivational, items recovered, forms of reuse and the actors that are involved in the process.

Reuse motivation can be due to economical and also ecological. In terms of economical, usually machinery parts can be reused with slight repairs and this saves cost as compared to manufacturing a new part. As for ecological concerns, companies are increasingly being pressured to take back all their sales materials for recycling purposes in order to be eco-friendly.

As for different types of materials recovered, the forms of reuse may vary as well. The different forms of reuse includes:

- **Direct Reuse.** Returned materials can be reused directly without major repairs except for cleaning. Examples of such products are bottles and containers.
- **Repair.** This process is to restore failed products into working order. However, the performance of the repaired product might be reduced.
- **Recycling.** This process recovers material without conserving any of the initial product structure. Commonly recycled items are scraps, paper and glass.
- **Remanufacturing.** This process differs from recycling in that the recovered product retains its original characteristics. Examples are automotive engines and machines.

Finally, there are also different actors involved in reverse logistics. Actors play different parts in the reverse logistics process such as collection, testing and product recovery. Due to the different actors involved in reverse logistics, integrating reverse and forward logistics pose a major challenge.

As stated in the problem definition section, there are many challenges in designing an optimum reverse logistics management system and integrating forward and reverse logistics. Most of the problems arose mainly due to uncertainties in the reverse flow of materials both in terms of quantity and quality and also the timeliness of the information gathered.

Below, we propose a model that integrates RFID technology into the reverse logistics framework to eliminate the uncertainties involved in the process. Furthermore, we will also employ genetic algorithm optimization technique to determine the optimum location for the initial collection point so as to maximize user coverage and reduce logistics cost involved in the process.

4.2 The Reverse Logistics Model

The physical flow and RFID data flow for reverse logistics process are shown in Figure 1. The main elements in reverse logistics includes end user, intial collection points, centralzied collection center and produccer.

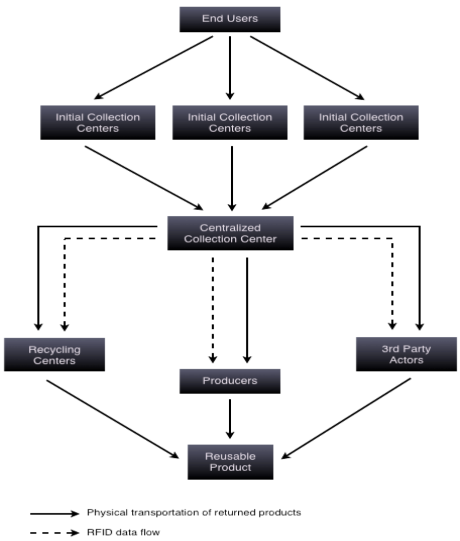

Figure 1: Flow chart of reverse logistics process.

4.2.1 End Users

End users are customers of the company who wishes to dispose off of their old products or are returning their products due to defects. End users would demand for convenience and accessibility. Hence, the initial collection points have to be loacated within short travelling distance to the customers.

4.2.2 Initial Collection Points

In order to determine the placement of the initial collection points, we shall employ the genetic algorithm optimization technique. The locations and density of population in an area are recorded and amount of initial collection center is determined. Using the genetic algorithm program, the optimum location to employ the initial collection center is determined.

Genetic Algorithm. Genetic algorithm is one of many population-based optimization techniques. Population-based technique induces a pattern whose present state depends on the past states; hence incorporate implicit memory structure (Min et al., 2003). Genetic algorithm is based on the theory of evolution whereby an initial population is generated, subsequently the population space are evaluated against a pre-defined function to remove inferior solutions. After that, mutation of strings will then occur and this process repeats until the optimum solution is found.

The Working Mechanism of Genetic Algorithm. Genetic algorithm technique starts with initialization. The close (0) or open (1) of collection point(cp) is encoded in the chromosome For instance:

cp_1 cp_2… …cp_n

1 0 1 1 1 0 0 0 1

After the initialization phase, the chromosomes in the solution space will be evaluated with reference to a pre-defined objective function. The chromosome with a higher score will be chosen to form an intermediate solution space. This is called the selection process.
For our reverse logistics determination of collection point, an example of the objective function would be as below:

$$\text{Minimize } \sum_{i=1}^{n} (s_i \cdot X_i + p_i \cdot X_i + h_i \cdot X_i)$$

FC: Fixed cost per unit of initial collection point
n: Number of initial collection points
VC: Variable cost of initial collection point
LC: Logistic cost per unit of returned product
OC: Other costs

After roulette wheel mate selection, one point crossover process (crossover rate 0.8) takes place. The crossover process selects a string randomly in the intermediate solution space and modifies its gens value randomly. This is to ensure that all possible solutions are explored and also to avoid the solution space from converging to a local maxima or minima. Example of how the mutation operator works:

parents	offspring
1 1 --- 1 0 0 0 1	1 1 --- 1 10 0 0
0 0 --- 1 10 0 0	0 0 --- 1 0 0 0 1

Exchange site

After the crossover operation, 2 new chromosomes will be formed and this will ensure diversity in the solution phase. Next step is mutation operation with mutation rate as 0.01. Unlike crossover operation, mutation involves only 1 gene. The operator randomly selects gens and assigns random value to it as shown below:

Before	After
1 <u>1</u> 1 0 1 <u>0</u> 1 0	1 <u>0</u> 1 0 1 <u>1</u> 1 0

The random gene alteration process also works to ensure that diversity in the solution set is maintained and that the solution do not converge pre-maturely to a local maxima or minima.

Finally is the replacement process. After the mutation has taken place, the chromosomes are then evaluated again against the objective function. Chromosomes with higher scores will then be chosen into the next round of mutation process while the chromosomes with lower scores are discarded. Through these processes, the solution space will converge to the most optimum solution desired.

Design Framework. As shown in Figure 2 and 3, using the genetic algorithm generator program, we could determine the location of initial collection point to achieve the best possible population coverage.

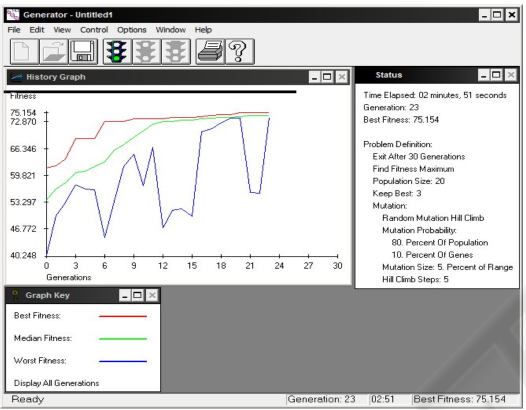

Figure 2: Genetic Algoritm Generator.

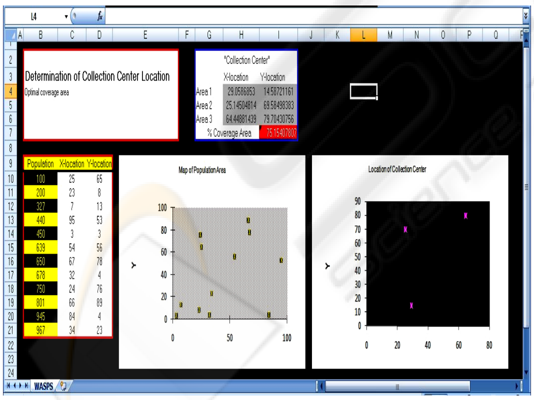

Figure 3: Determination of initial collection point location.

However, this method of optimization is based on an ideal case scenario. The program does not take into account factors such as accessibility and convenience to the end users. Therefore, the model above is merely an indication of the approximate location. Even so, we could still employ the knowledge acquired above to be applied when making a final decision on the placement of the collection center.

Furthermore, a collection schedule will have to be planned for regular pick-up at the initial collection center back to the centralized collection center. Due to the limited space available at the initial collection centers, pick-up schedule has to be regular and frequent. Planning of the pick-up schedule is not covered in this paper.

4.2.3 Centralized Collection Center

The centralized collection center is a place where all the return products will be sent to from the initial collection center. This is where the returned products will be sorted, stored and distributed to undergo their respective process. Hence, the centralized collection center is where the workflow begins and is where we shall employ RFID technology to optimize the efficiency.

Radio Frequency Identification (RFID) for Reverse Logistics. Radio Frequency Identification or RFID has moved from upcoming technology to mainstream application in recent years. RFID is currently been used to replace the tradition bar-code system as it can read data without the need of being in line-of-sight and the RFID tags can store much more data than bar codes. Among the earliest adopters of RFID includes Wal-Mart, Tesco and the US Department of Defence (Want., 2007). However, most of the usage of RFID at them moment is mainly focused on the forwards logistics. In this paper, we will integrate RFID technology into the reverse logistics system to overcome problems faced in the system.

RFID Working Principles. The very fundamental working of RFID technology is based on electromagnetic wave (EM). There are 2 different types of RFID designs, mainly: Near field RFID and Far field RFID. Near field RFID operates based on Faraday's principle of magnetic induction. This system uses EM waves to power the RFID tag and the tag transmits data back to the reader through load modulation. Range of operation for this system varies inversely with the frequency of operation while energy from induction reduces with distance. Far field RFID on the other hand captures the EM wave propagated from the reader and reflects back the EM wave through the embedded antenna on the tag. This method of operation is known as back scattering. The reader will then receive the reflected wave pattern and interprets the data. Operational range for this system is limited by the amount of energy received by the tag from the reader.

Types of RFID Tags. There are 2 types of RFID tags: active and passive. Active RFID tags require power source to operate. This power source can be either from a power infrastructure or an integrated battery. Since the tags require external power source, they have limited lifespan. On the other hand, passive tags receive power from the RFID reader. Hence they are only activated upon being read by the reader and have unlimited lifespan. Furthermore, RFID tags shown in Figure 4 come in different shape and sizes for different usage purposes. There are also different types of tags for use on different material surfaces.

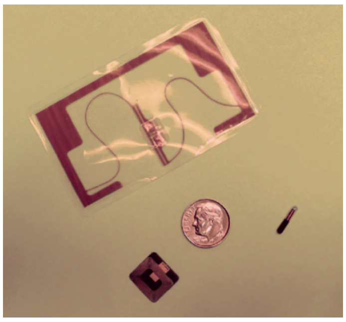

Figure 4:Different shape and sizes of RFID Tags (Want., 2007).

Advantages of RFID for Reverse Logistics. RFID technology provides numerous advantages for the proposed model in reverse logistics processes. Among the advantages are:

- No line-of-sight needed. This enables data to be read from the tag in returned products at any orientation and hidden away from sight.
- Long-range reading is also possible with RFID. This enables the reader to be at a distance away from the tag while still being able to read the tag. This is an added advantage for logistics purposes.
- Multiple tag reading is also supported by RFID. As compared to bar-code system, which can only read 1 bar code at any one time, RFID can read multiple tags at the same time. This will enable the returned flow of products be read at once when passing through the RFID readers.
- RFID technology also allows for real time tracking. When the returned product is in range of the RFID reader, it will be read immediately without human intervention. The data read by the reader can subsequently be sent to the respective actors involved in the reverse logistics process.

RFID Constraints in Reverse Logistics. Even though RFID provides a huge amount of advantages over traditional system, it is not without its own disadvantages. Chief among them are:

- Orientation of tags relative to the reader. Although RFID tags do not require line-of-sight for reading, however under certain orientations, RFID tags can be hard to read. This will pose a problem as the returned products would be oriented randomly and this could prevent the reader from reading the tags effectively.
- Signal blockage. If the returned product is made of metal casing, the RFID tag could be enclosed in the casing causing EM wave to be unable to penetrate the metal case and hence will not be able to be read. This constraint is particularly pronounced when tagging components that are enclosed in a casing such as computers, television sets and others.
- Cost. At the time being, the cost of RFID hardware is still high. Moreover, reverse logistics is usually seen as a cost center for most companies and are not revenue generating. Hence, companies are reluctant to invest huge amount of money in this technology. However, this cost is dropping as the system gets more commercialized and more companies adopt the technology.
- Privacy. Privacy is also a concern for end users, as they fear that companies can still track the products after consumers have purchased it. However, certain measures have been taken to address this issue.

In this paper, we have worked within the limitations imposed by RFID technology to implement RFID to design a better reverse logistics management system. At the centralized collection center, RFID system can be set up at the point of entry to scan each and every collected product that has been tagged. An important assumption made in this research is that tagging is done at the forward logistics process and is carried down to the reverse logistics process. The RFID reader can read every tag passing through the entry point and the system will relay this information to the control centre.

With this data acquired through the RFID reader, we are able to tell the quantity and type of product returned in real time and without much human intervention. This solves part of the unknowns in the reverse logistics process. With the data acquired, different products can be sorted according to their respective category and this reduces time wastage in between handling.

4.2.4 Producers

Fianally, the loop ends at the producer of products who receive the returned flow of material and convert it back to usable products to be sold back to the end users. This cycle will repeat and make up the reverse logistics process.

4.3 Case Example

As a summary of the whole process, a company (eg. Apple Computers) can employ RFID technology to tag all of their products during manufacturing. This RFID tag will be used during the forward logistics to replace bar-code technology. The tag will remain with the product until the consumer decide to dispose off of the product. Hence, the consumer will return the product to the initial collection center situated at various location throughout the area. A routine collection schedule will ensure that returned products are collected regularly from the initial collection center back to the centralized collection center. Once back in the center, the RFID reader situated at the entrance will read the tags on the returned product and disseminate the data to the control center. This data will then be used to activate the various work flow associated with each and every returned product. Finally, the returned product can be recycled and sent back to the original producer to be made into new products and distributed again.

5 CONCLUSIONS

In this paper, we formulated a model that integrates Radio Frequency Identification (RFID) into reverse logistics management in order to eliminate part of the unknowns in the process. By doing this, we are able to better plan and optimize the reverse logistics network. Furthermore, we also utilized genetic algorithm optimization technique to determine the optimum location of initial collection points. This will enable us to further reduce logistical cost involved in reverse logistics. However, further study about model evaluation with real-time data should be done and comparing GA with other optimization techniques can be carried out to show the effectiveness of GA. We believe this paper could be a reference point for further research to be performed upon.

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REFERENCES

ReturnBuy. The new dynamics of returns: the profit, customer and business intelligence opportunities in returns. Ashburn, Virginia; White Paper; 2000, ReturnBuy.com.

M. Fleischmann, J.M. Bloemhof-Ruwaard, R. Dekker, E. V. D. Laan, Jo A.E.E. van Nunen, L. H. Van Wassenhove, "Quantitative models for reverse logistics: A review", European Journal of Operational Research 103, 1997, pp. 1-17.

R. Want, "An introduction to RFID technology", Pervasive Computing, January-March 2006, pp 25-33.

V. D. Hunt, A.Puglia, M. Puglia, RFID: A Guide to Radio Frequency Identification. Wiley-Interscience, 2007.

H. Min, H. J. Ko, C. S. Ko, "A genetic algorithm apporach to developing the multi-echelon reverse logistics network for product returns", Omega: The International Journal of Management Science, vol 34, 2003, pp. 56-69.