Meta-Heuristic Based Model For Decision Support Application Of A Reverse Supply Chain

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A Decision Support System (DSS) for reverse logistics of passenger cars for reuse after reconditioning Operation has been presented in this paper. A DSS demonstrated employs meta-heuristics based Information and Communication frame work for application in reverse logistics by building the virtual network. The DSS generate routes that satisfy all model constraints using artificial intelligence-based optimization methods, innovative wireless telecommunication facilities and GIS technology, all integrated within an ERP framework. The proposed DSS enables the re-use market elements to interactively approach reverse logistical problems.

1. Introduction

Reverse logistics, the analysis of process and operations involved in the reuse of discarded/used-up products, Commercial returns, excess inventory of products and materials, is gaining crucial importance in modern day's Supply Chain Management. If we use the capability of Information and communication technologies, volume of incoming returns can be maximized and inherent uncertainty can be minimized. IT infrastructure can supplement and substitute some of the operations involved in reverse logistics, for, it is fortified with power of information processing technology and runs on least ambiguous platform from costs and required time point of view. This modified infrastructure will have virtual network of information.

This paper proposes architecture for these virtual reverse logistics networks and describes an electronic marketplace coupled with virtual reverse logistics networks to facilitate redirection of returns in the market. We take a case of automobile industry (Family cars) of Indian market, where the scene of re-using the vehicles is gaining vast importance, both commercially and socially.

Further, virtual reverse logistics interfaces can be used to offer incentives to set optimal policies for time and methods of collection for returns. Virtual reverse logistics networks enable higher visibility on products data, even before products enter the returns flows. For certain classes of products, these data can be used to accelerate their 259e-entrance in a reverse logistics network. For example, consumer electronics can not afford to get stacked idly because they get depreciated literally by the day; a virtual reverse logistics network for consumer electronics can be used to for seamless redirection of excess inventory or commercial returns into the marketplace.

This paper proposes a Decision Support system (DSS) for the effective management of used automobiles' re-entrance to the market place, for the use of secondary customer, thereby forming a reverse network for the supply chain. The system enables managers to address planning and reverse logistics problems, and monitor complex operations using novel computational methods and web-based applications. The motivation for this research stems from the interrelationship between commercial considerations of the automobile industry and benefits of reusing the products. The DSS incorporates intra-city Heterogeneous Vehicle Routing with practical and complex operational constraints as well as monitoring of complex reverse collection operations. The DSS generates routes that satisfy all model constraints using artificial intelligence-based optimization methods, web-based telecommunication facilities and GIS technology to transform these processes into seamlessly running systems.

1.1 Research Course

The architecture of the proposed DSS involves an integrated framework of Geographical Information Systems (GIS) technology coupled with interactive communication capabilities between peripheral tools. The overall system mainly consists of the following components (see figure 2 given at the end): Secondary

Demand (SD), Vehicle Routing (VR) and Re-use Potential Monitoring (RPM). The components are explained with a literature survey base.

1.1.1 SD Component

The SD component includes surveys and queries from the market place, which provides for Data collection and regeneration planning tools and the set of collection points to be serviced and estimates the quantity of the automobiles required for reuse.

1.1.2 VR Component

The VR component employs artificial intelligence optimization methods for solving the shortest path and vehicle routing and scheduling problems, provides turn by turn navigation and route summary reports to the collection vehicles.

1.1.3 RPM Component

The RPM component offers real time information on the exact location of each collection vehicle and data concerning condition of the vehicle, and requirements of the primary customer.

The emergence of accurate and sophisticated GIS technology, and easy-to-use interface software, enables companies to integrate routing with other key functions such as inventory tracking and fore-casting. [Reference 6] have developed an internet-based logistics management system to coordinate and disseminate tasks and related information for solving the heterogeneous vehicle routing problem using appropriate meta-heuristic techniques. [Reference 1, 2] Tarantilis & Kiranoudis developed a Spatial DSS to provide and manage related information for solving the Composite VR using a backtracking adaptive threshold accepting metaheuristic method. [Reference 5] presented a DSS and implemented a number of heuristic algorithms to address the Heterogeneous VR with soft time windows. [Reference 3] have proposed adaptive memory programming algorithm for solving the VR Problem.

2. Problem Description

The Automobile data collection for the reverse logistics and regeneration processes involve the upstream movement of automobile data from several sets of collection points to the central regeneration facilities, where automobiles are reconditioned (see figure 1).

To-date, planning is empirically performed, without considerations of actual MPS or other practical concerns (e.g., rate generation of number of vehicles being re-furbished at storage depots. Automobile then is in for multi-stage regeneration, which is a continuous process requiring part replacement or upgrading, depending upon the variant.

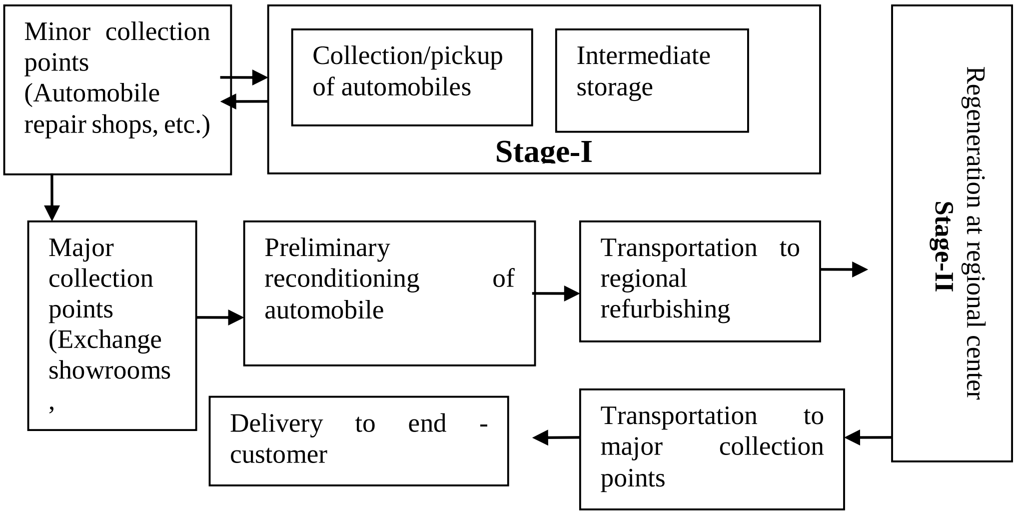

Fig. 1 Reverse logistics framework

2.1 Methodology

We propose a DSS to address planning and scheduling needs of automobile regeneration, a fact further reinforced by the explosion of the collection points participating in the recycling operations.

From a VR perspective, automobiles collection has a number of characteristics that complicate a DSS for management of vehicle's re-entry to the secondary market. The routing and re-furbishing require special handling beyond the simple pickup operation captured by the standard VR Problem.

Below, we list and discuss these distinctive features of the automobile collection problem.

i. **Multiple Commodities:** automobiles often come in multiple quality levels, e.g. different fuel injection method, or different cubic volume displaced, over and above other standard luxury features. Obviously, the automobiles' multi-commodity nature is of great importance, as the pressure of customizing production increases.

ii. **Hierarchical order Collection Problem:** The automobiles collection operations involves two stages, i.e., from several sets of collection points (e.g. exchange depots, registered entries at automobile repair shops, industrial facilities etc.) to the intermediate automobiles storage depots (transfer points), and from these to the central storage facilities of the regeneration/refurbishing plant (see Figure 1). Transfer points refer to intermediate storage locations used to accumulate automobiles collected locally. The way automobiles move as inventory to the production facilities does not affect local collection. Moreover, in some cases, additional processing (preliminary repair/part replacement) is performed at the transfer points before the release of the automobiles to the second stage. In our study both stages of the automobiles collection problem are explicitly considered. Therefore, the automobiles collection problem can be viewed as a hierarchical routing problem.

iii. **Route Duration Constraints and Time Windows:** Although the majority of collection points do not pose any time window restrictions there is a small portion that may pose a pre-specified soft time window. Moreover, there is a particular time horizon for collections, which is governed by the earliest and the latest time that the central or intermediate storage depots operate. Finally, depending on the quantity of automobiles loaded to the collection vehicles the service time may vary.

iv. **Nature of Collection Points:** We distinguish collection points into minor and major. At minor collection points (e.g. automobile repair shops) the available quantity of automobiles and its accumulation rate are relatively small, with varying input grades (automobiles quality). On the other hand, major collection points (e.g. Authorized showrooms and distribution facilities) produce large quantities of single graded automobiles, with near constant accumulation rate. During collection planning, the sizes of pickup quantities play an important role; therefore, one may expect these variations to considerably affect the vehicle routing schedule.

v. **Interaction between regeneration and Collection:** An interesting feature of automobiles collection is the interaction between production planning, inventory control and automobiles collection itself. The need for automobiles is determined by the customers' demand for new automobile. Inventory can be considered as the absorber of automobiles daily collection level variability and customer demand. Theoretically, keeping excessive inventory has a determinant effect on inventory handling costs. On the other hand, a minimum inventory is required to ensure the smooth availability of the automobiles (without shortages). Moreover, the desired regeneration sequence minimizes the set up and makeover times for reusability. Therefore, although the collection is not directly connected to the refurbishing, automobiles' daily collection requirements are expected to vary considerably. In practice, one has to devise a production schedule that offers a compromise between production effectiveness, inventory costs and vehicle scheduling requirements.

vi. **Vehicle Fleet & Capacities:** The capacity of the vehicles is expressed as the maximum volume each vehicle can hold. Every vehicle includes multiple compartments, each characterized by a distinct capacity. All compartments can accommodate different automobiles' grades. The vehicle fleet is heterogeneous with respect to the capacity and the number/volume of compartments vehicles. Moreover, the fleet necessary for the first stage of automobiles' collection differs from the vehicles performing the routing for the second stage.

3. Decision Support System presentation

Automobiles' collection and refurbishing is a complex process involving multiple agents and stakeholders. Consequently, the proposed DSS has to address all issues pertaining to the production plant, the automobiles' storage depots, the collection points and the vehicle fleet. The three major questions that the DSS should tackle are: i) how many automobiles' must be available in the central storage facility in order to allow for smooth demand-satisfaction based on the actual end-item requirements; ii) how to effectively schedule the collection process by the heterogeneous vehicle fleet, considering all practical and operational constraints; and iii) how to continuously monitor the operations of the vehicles to ensure full automobiles' retrieval/reconditioning. The proposed system architecture, which provides answers to these three questions, is presented in Figure 2 (given at the end) and its components are briefly described below.

3.1. Reverse MRP

The RM component includes waste collection and automobile regeneration planning tools, provides the set of collection points to be serviced and estimates the quantity of the automobiles required for regeneration. Given the output of the MRP system (gross requirements for automobiles), a new reordering point model is used to estimate the volume that must be collected daily, in order to ensure that production is met and no stock-outs due to supply-uncertainty occur. Several filtering procedures are employed to assign priorities to collection points and intermediate storage locations, while a list of collection points is the output and the decision maker is prompted to approve or modify the list according to operational or strategic realities.

The Reverse MRP procedure links the demand for automobiles with the collection phase. The whole procedure is realized through a set of functions that are primarily linked to the company's ERP system. Through the ERP/MRP routines, the automobiles' requirements are generated on a daily basis and are filtered by the "Regeneration Requirements" module (see Figure 2 given at the end). This filter takes into account current inventory status and also controls the ordering routines for automobiles with similar characteristics to the regenerated automobiles. Thereafter, the quantity required is filtered by the "Q, r model" module. Usual (Q, r) inventory control models deal with stochastic lead times and/or stochastic demand. In our case, lead times are fixed and demand is known from the "Regeneration Requirements" module. However, the replenishment quantity Q (the quantity finally collected) is a stochastic variable. To overcome the uncertainty of the replenishment quantity that might induce irregularities to the regeneration process, the desired quantity Q is changed to Q´ by the (Q, r) model routine.

Historical data about the ratio of automobiles ordered/demanded compared to automobiles collected is used to determine the distribution of this stochastic variable as well as the distribution parameters (mean and standard deviation). Finally, an acceptable value of the above ratio is chosen (user defined) and the quantity Q´ can be easily calculated. Given the above defined collection quantity, the set collection points to be visited must be determined. The collection area is divided into distinct zones called Storage Locations. Each collection point is assigned to a specific storage location. Data is received continuously from all collection points related to the status of their storage levels. Based on this data, a specialized meta-heuristic assigns priorities to the collection points; the output of this set of routines is a list of collection points for each storage location. Provision can be so made that although this list is generated by the system, a decision maker is prompted to approve or modify the list according to operational realities. The decision maker is requested to decide which storage locations will contribute to the collection (desired quantity) and to what extent. Having determined the storage locations and the sorted list of collection points, the VR component is triggered.

3.2. Vehicle Routing

A GIS, in which artificial intelligence optimization methods for solving the shortest path and vehicle routing problems are integrated, is used. The VR component provides high quality solutions and offers turn-by-turn navigation to the vehicles. An arc based Dijkstra algorithm which considers turning restrictions and actual network information is applied to determine shortest paths from/to each collection point and intermediate or central storage facilities. A two-stage Tabu Search meta-heuristic handles the Heterogeneous Fixed Fleet Vehicle Routing Problem with the practical and complex operational constraints, which models the collection operations. Due to the problem’s real-life constraints, it is difficult to find feasible initial solutions.

In our approach, we have initially relaxed the fixed fleet constraint and have used a combination of limited and unlimited number of vehicles. The proposed methodology uses the fixed fleet of vehicles to serve as many collection points as possible and then, if there are any un-routed collection points, generates new vehicles to serve them. Using this rationale, an initial solution is produced. Given the initial solution, an enhanced Tabu Search meta-heuristic is applied to improve the solution quality and reduce the vehicle required; using problem specific neighbourhood structures.

The shortest paths, expressed in terms of travel time or distance travelled, within a specific road network, are determined through an enhanced Dijkstra’s algorithm, which is used in two separate cases during the process of developing the routing plan. In the first case, it calculates the travel times between all possible pairs of depot and customers so that the optimizer would generate the vehicle routes connecting them, and in the second case it determines the shortest path between two nodes (collection points) in the routing plan, as this was determined by the algorithm previously. Due to the fact, that left-right turn restrictions were taken into consideration for network junctions, an arc-based variant of the Dijkstra algorithm was implemented. Actual segment preferences are also explicitly considered.

3.3. Re-Use Potential Monitoring

The RPM component provides real time information on the location of each vehicle (via GPS and web technology) and data concerning automobile numbers for re-sale and accumulation rate at each distributed collection point or intermediate storage facility via a simple web-technology using Information and communication network. Briefly, RPM component ensures and provides: a) On-line continuous monitoring of all stages of automobiles’ collection; and b) On-line secondary demand data and accumulation rate records of major collection points and intermediate storage locations.

4. Present Status

The research contributions emanating from the proposed DSS could typically be a) extensions of the Dijkstra algorithm to accommodate turning restrictions and actual road segment preferences in urban street networks; b) effective multi-stage tabu search for a difficult variant of vehicle routing with practical and complex operational constraints; c) adaptation of the (Q, r) inventory control model for the case of supply uncertainty; d) integration with actual ERP systems for seamless data flow; e) integration with ICT systems for accurate vehicle monitoring.

5. Future scope

The proposed DSS uses web-based technology for information gathering from distributed sources, and artificial intelligence optimization methods to optimize the production and recycling procedures, in order to improve substantially and monitor the overall performance of the production and collection operations effectively.

The DSS provides a vital platform that could improve productivity and competitiveness and can become potential ideal solution for day-by-day expanding market of pre-owned automobiles, specifically passenger cars.

6. References

[1] C. Tarantilis and C. Kiranoudis. (2002), Using a spatial decision support system for solving the vehicle routing problem. Information & Management, 39:359–375.

[2] C. Tarantilis, C. Kiranoudis, and V. Vassiliadis. (2004). A threshold accepting metaheuristic for the heterogeneous fixed fleet vehicle routing problem. European Journal of Operations Research, 152:148–154,

[3] C. Tarantilis, D. Diakoulaki, and C. Kiranoudis. (2004). Combination of geographical information system and effective routing algorithms for real life distribution operations. European Journal of Operations Research, 152:437–453.

[4] J. Jiang, G. Han, and J. Chen. (2002), Modelling turning restrictions in traffic network for vehicle navigation system, In Proceedings of the International Symposium on Geospatial Theory, Processing and Applications, Commission IV, Ottawa.

[5] J. M. Belenguer, E. Benavent, and M. C. Martinez. Rutarep. (2005), A computer package to design dispatching routes in the meat industry, Journal of Food Engineering, Greece

[6] M. Gendreau, G. Laporte, C. Musaraganyi, and E. Taillard. (1999). Computers & Operations Research, 26:1153–1173,

[7] N. Prindezis and C. Kiranoudis. (2005), An internet-based logistics management system for enterprize chains, Journal of Food Engineering, Greece

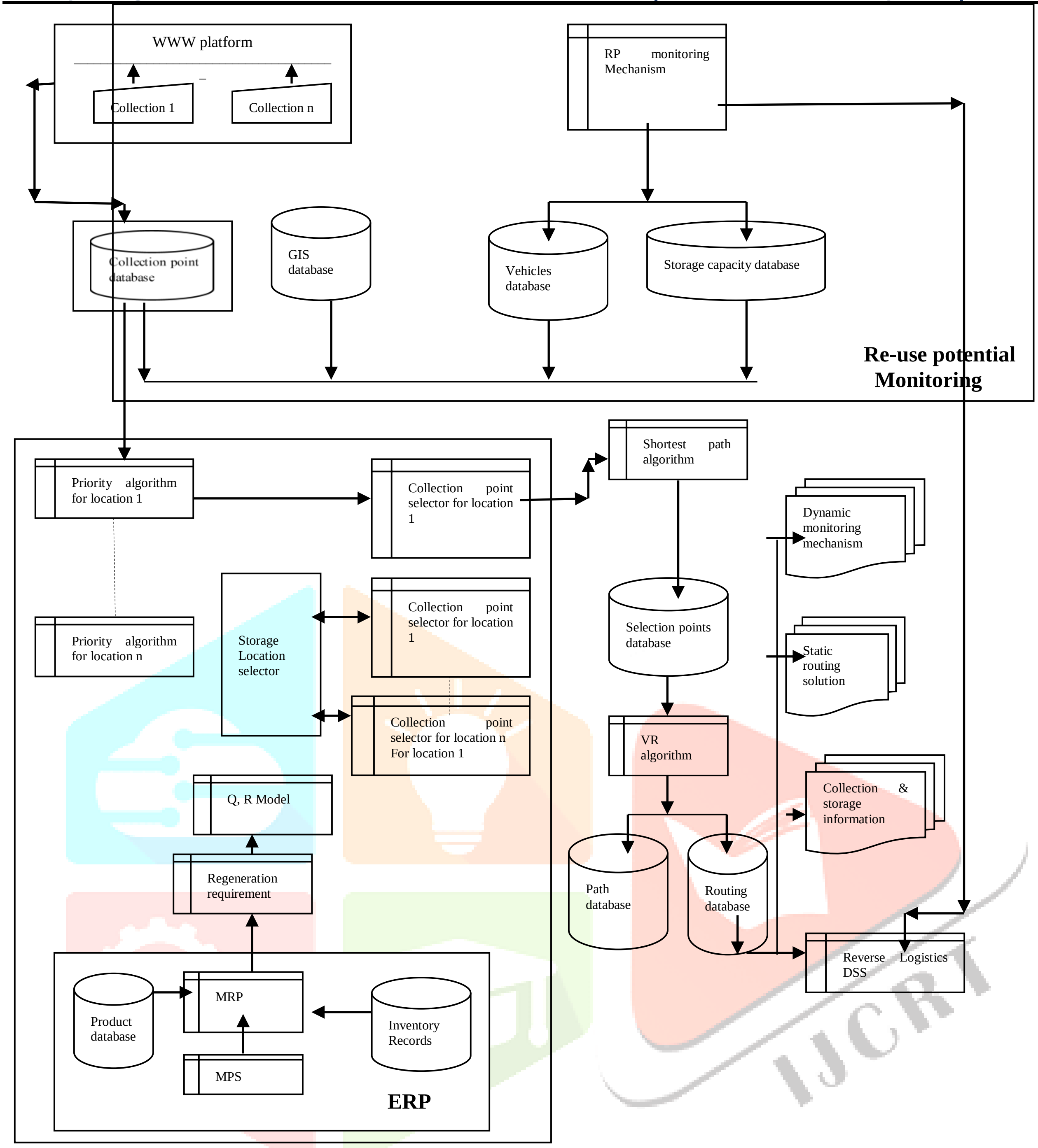

Fig.2. Composite DSS architecture