© International Journal of Combinatorial Optimization Problems and Informatics, Vol. 7, No. 3, Sep-Dec 2016, pp. 44-53. ISSN: 2007-1558.

State of the Art of the Different Models of Transportation Most Used in the Supply Chain of Automotive Industry

Gabriel Policroniades Chípuli, Idalia Flores de la Mota
Universidad Nacional Autónoma de México

gpolicroniadesch@gmail.com, idalia@unam.mx

Abstract. Recently, automobile manufacturers are trying to procure parts using the Milk-Run logistics at most of their nearby suppliers and others kinds of consolidation applied to their distribution system with far suppliers. This article shows generally a state of art of this kind of consolidation used in the automotive industry. However, it is important to mention that the process of Milk-Run does not apply to all levels of the supply chain; only between the shipbuilder and nearby suppliers. All this leaves devoid of a transport mechanism of equal magnitude to the other levels or supply chain; allowing the modeling of different transport models that provide solutions to each specific distribution system depending on the type of consolidation. These models are based on the vehicle routing problems (VRP) and its various aspects; which are mentioned in this work.

Keywords: Milk-Run, Consolidation, Automotive Industry, VRP

1. Introduction

The automotive industry, is considered as "the industry of the industries" [1], due to its high level of consumption and requirements of thousands of components from all over the world [2]. The classic vision of having suppliers nearby or making the products 100% independently was lost over time; in search of the optimization of the processes. With suppliers from all over the world, the reduction of raw material costs is another important factor generated as a consequence of this situation; in response to this, the supply chain in automotive sector presented radical improvements to the existing classical processes, generating a vision for supply chain management rather than manufacturing [3], [4].

During the 20th century, as mentioned in [5], the automotive industry has been a major contributor to supply chain management. One of the most important applications in this sector has been the use of the Milk-Run concept, or "Milk Cow" as a system of consolidation of finished product between the manufacturing companies [6]. Another definition of this type of system is shown by [7]; who defines it as a cyclical transport system which is operated manually to transport raw material or finished product through a settled down route or schedule. This type of transport is advisable to use when suppliers are located at a close distance between them. However, [8] identifies three types of product consolidation existing in this type of sector.

This paper is organized as follows, in section 2 will be found the state of the art of the three types of consolidation of the finished product in the automotive sector; However, due to the high complexity of the supply chain, some of these consolidation models present mixtures between them or variants that are applicable only to a particular company; Which indirectly leads to the analysis of the vehicle routing problem. In section 3, will be analyzed some problems that cannot be approached by the models previously mentioned; making necessary the use of another technique like the sciences of complexity.

2. State of the Art

Prior to the state of the art, the process by which the delivery of the finished product is logistically performed consists of three different parts; The first of them, the request of the order; The second, the logistics logistic process; And the third stage, the return of empty containers if there is such a process [9].

Nemoto et al., (2010) identify three main types of distribution of the finished product in the automotive sector based on the consolidation process; The first of them, the Milk-Run logistics process; The second, consolidation at the point of shipment of the supplier; And the third, consolidation at a cross-dock.

Received Jan 29, 2016 / Accepted Aug 21, 2016

Boysen et al. (2015) state that these types of consolidation and delivery are governed by the JIT (Just In Time) factor demanded by auto parts suppliers in order to comply in a timely manner with product delivery. Another aspect that could be observed within these transport models is the multimodal factor, which mentions it [10] within the automotive sector, or any type of industry with similar distribution models.

Lawson et al. (2016) on the other hand, mentions that many of the logistical aspects can be considered during the design process of the vehicle looking for a significant cost reduction from the beginning; which he calls Development by Virtual Reality within the automotive sector; visualizing the whole system in particular.

2.1 Milk-Run

This model of transport, as already mentioned, is also known under the name of "Milk Cow System", based on the milk sales system, in which the milkman walks door-to-door delivering the milk in established route in which in the end will travel the same route to collect the empty containers [6].

Nemoto et al. (2010) explain that the importance of the Milk-Run lies in the synchronization between the manufacturing cells and the transport process under the JIT regime. That is, only the delivery of the necessary parts for the production is carried out drastically reducing the inventories and the pieces possibly defective; another important feature of this factor lies in the search for the minimization between the quantity produced and the quantity demanded.

One consideration, which is done when carrying out this type of transport, lies in a Lean transport process, under the concept of lean manufacturing, using the Kanban concept [12]. This ensures that quantity of the product demanded is exactly what is needed to meet the production requested; leading indirectly towards an ecological policy by reducing the number of containers and the CO2 emissions caused by the use of vehicles [2], [8], [6].

Prior to the introduction of the "Milk-Run", the distribution and collection were carried out in a classic way, what means that a vehicle for delivery and a vehicle for collection; which is mentioned in [6] and [13].As a result, they had a generation of a bigger use of vehicles and a lack of optimality in the spaces of a load of the vehicles; which contrasts it[14] with the Milk-Run.

On the other hand, [6], they comment that one way to alleviate the problems of transport between the manufacturers and near providers, is the use of this model of transport; Which, according to the authors, generates an economic benefit when, through the travel of a vehicle, it is possible to collect the finished product from several suppliers, before reaching its maximum load capacity for delivery at the end client.

Yun et al. (2010) analyze the interaction between the inventory control and the transport model using a genetic algorithm applied to the Milk-Run. Hosseini et al. (2014) develops an entire programming model for a Milk-Run model with the characteristic of a Cross-Docking; however, because of the complexity of the problem, it is necessary to develop a hybrid heuristic algorithm that would allow him to find a solution; for its analysis makes the assumption that all vehicles have the same capacity. Their results, obtained through GAMS / CPLEX, obtain the exact values of 10 instances; while the hybrid algorithm achieves practically the same results improving execution times remarkably.

2.2 Consolidation at the Transfer Point

This process, as mentioned [8] occurs when there are two or more manufacturers or plants that depend on a single supplier. In this case, the merchandise is consolidated at the point of departure of the supplier and distributed to different points; which can be located both near and far.

2.3 Cross Dock Consolidation

A cross-dock, as defined [16] is a point where materials are unloaded from incoming vehicles and loaded into a vehicle with a defined route to a customer. In this regard, a provider could have such points on their distribution channel. An important feature of these is that their location must be carefully analyzed in order to be as close as possible to the desired end point. On some occasions, these points can get to operate as 3 "Party Logistic Firm" (3PL); That is to say, places where the products are almost assembled and in these, the assembly is completed or the load is consolidated.

Klincewicz et al. (1990) refers to the use of one or more points of consolidation as the way of generate savings in the long term. [16] develops a mixed programming model to solve a real case of the Bosch company to make a distribution model under two different premises; the first one, to create subgroups of supplier clients, where consolidation was carried out in the same location; and the second, using a crossdocking, which, it was observed that greater savings were obtained.

2.4 Some Related Transportation Models

The Milk-Run model is commonly used between the second and third tier of the supply chain; Being these levels focused to the main manufacturer and the manufacturer nearest with products that economically represent a saving in the use of this type of model.

On the other hand, a company may also have combined consolidation systems; That is, it may be within the consolidation regime of a Milk-Run if it is close to the main manufacturer; And have another delivery system if you have more customers at a greater distance. This effect generates a greater complexity in the transport model that will characterize it.

Andreatini et al. (2014) mentions that there is no generic mathematical model of the same magnitude as the Milk-Run for these levels; leaving to the freedom of these companies the creation of their transport models. These transport models have usually customized versions of the VRP depending on the individual problem.

In the transport models of the automotive sector, there is a factor that is repeated constantly; this factor is the environmental aspect [19] and [20] comment that a few decades ago the awareness of sustainable development was so strong that the transport models presented a substantial change in their development. As a response to this, the name of reverse logistic or green logistic is coined to all those processes in which there is a collection of waste or returnable products that return to their source; this policy is also called Reverse Logistic [21].

Das and Chowdhury (2012) mention in general that this type of logistics can be applied to the different consolidation methods mentioned above or through retailers. Nieuwenhuis et al. (2013) develops a study to identify, based on the impact of CO2, how convenient it is to have suppliers within the same region, or with suppliers outside of it.Toro et al. (2016) shows a more detailed state of the art as illustrated in the present article starting from the different aspectsof the *VRP*. Kumar (2013)and [26] perform a simpler classification; the first author starts from the VRP and covers a general classification of these models; While the second author focuses only on the VRP models with Collection and Delivery.

On the other hand, to these models mentioned above it is possible to add cargo accommodation restrictions within the vehicle body; some loading constraints and state-of-the-art analysis of these types of problems can be found in [27].In figure 1, the aforementioned classification is schematically shown. Leung et al. (2013), they mention that customer demand is usually expressed in terms of volume or weight; to these considerations, it is possible to assign two or three dimensions of cargo within the box of a vehicle; depending on the type of container and its different stowage and fragility restrictions.

The two-dimensional problem, or 2L-CVRP; where the index 2L or 3L, as the case may be, is referred to the level of dimensions used to make a load accommodationaccording to [29]. With respect to the routing models mixed with load problems mentioned abov*e*, the work of [30] could be added, who carry out a detailed state of the art; It is shown in Table 1 that different contributions are presented and their scope in terms of the type of load restriction.

Table1. Contributions related to different transport models mixed with loading problems, source based on [30].

References	a	b	c	d	e	f	g
[31]	√	√	√	√	√	√	√
[32]	√	√	√	√	√	√	√
[33]	√	√	√	√	√	√	√
[34]	√	X	√	X	X	X	√
[35]	√	X	√	√	X	√	√
[36]	√	X	√	√	X	√	√
[37], [38], [39]	√	√	√	√	--	--	√
[40]	√	√	√	√	--	--	√
[41]	√	√	√	√	--	--	√
[42]	√	√	√	√	--	--	√
[43]	√	X	X	X	X	√	X
[44]	√	X	√	√	X	X	X
[45]	√	√	√	X	X	√	X
[46]	√	√	√	√	√	X	X

Continuation of **Table 1.**

References	a	b	c	d	e	f	g
[47]	√	√	√	X	X	X	X
[48]	√	X	√	√	X	X	X
[49]	√	X	√	√	X	X	√
[50]	X	X	X	√	X	X	√
[51]	√	X	X	√	X	√	X
[52]	X	X	X	√	X	√	X
[53]	X	X	√	X	√	√	X
[54]	X	X	√	X	√	√	X
[55]	X	X	√	X	√	√	X
[56]	X	X	√	X	√	√	X
[57]	X	X	√	X	X	√	X

Where:

a) Classic Constraints of BPP (Container Load Problem): Theelementscannot is stacked, buttheymust be contained in the box of thevehicle.
b) CapacityRestrictions: The total sum of theweights of eachpackagewithin a vehicleshallnotexceedits total capacity.
c) Orthogonality Restrictions: Thepackagesmust be loadedkeepingtheparallelwiththewalls of thevehicle box.
d) OrientationRestrictions: Thepackagemust be placed in a fixed position insidethevehicle box.
e) Fragility Constraints: Elements can be classified as fragile and non-fragileelements; Thefragilecannotbearanyweight.
f) Stability Restrictions: When a packageislocated at the top, oronsomeother, stability of thepackageshould be ensured.
g) LIFO load policy: This policy will allow the loading of the product as the delivery route is carried out.

3. Some cases not analyzed by these models

Gallotti and Barthelemy (2014) mention that in reality, transport problems can become so complex that when they are abstracted into mathematical models, they lose variables and interrelations that could be significant for a greater understanding of the system in general. One of the sciences that in the last years is addressing this type of problems and that considers all these characteristics, are the sciences of complexity.One proposal made by the authors is the use of multilayer networks for models with multiple types of transport; where each of the transport types generates a different layer in the general network.In addition, they mention that most of the complex systems existing in the real world tend to operate under the concept of multiplex network interacting with each other to result in the emergence of the system.Multi-layer networks allow the model to be abstracted including arcs and nodes with attributes and specific characteristics that cannot be realized in traditional network models.

Within these sciences, Complex Systems are located; For which there is no specific definition; however, there are features that make those easy to identify.

Some of these characteristics as mentioned in [60], [61], [62], [63] and [64]; are: Connectivity among its elements, interdependence, Diversity of agents, adaptability to changes in the environment, sensitivity to the initial conditions, and present a nonlinearity or emergence arising from the interactions between all its elements.

The first authors mention that a transport model can be represented like a network composed of interconnected arcs and nodes, where more characteristics of the system can be introduced with more detail if the concept of complex system is used; In this way, the authors propose that if one wishes to get closer to reality, one must try to address these problems by making use of the complexity sciences.

4. New contributions and research lines

The following section is based on the analysis performed by [65]; who develops a complete study of the state of the art of the different VRP models and their different solution techniques shown in table 2; In the table, a column with the updated articles corresponding to the year 2016 has been appended.

Table 2. Different solution techniques for diverse transport models in the literature; based on [65]

Applied Method	Number of Models	2009-2015 [65]	2016
Metaheuristic	247	233	14
Exact Method	4	56	4
Classical Heuristic	2	32	2
Real-Time-Solution Method	0	11	
Simulation	0	7	
* Other Techniques	1		1

In Table 2, an indicator named with other techniques can be identified; this is referred to other optimization methods than those mentioned; Or some combination of these. An example, is the work of [66] who proposes the use of agents with the ability to adapt, cooperate and search for new solutions as would a metaheuristic algorithm.

Based on this analysis, and in the study carried out by [27],it can be inferred that the evolution of the techniques used to solve this type of model has gone from the basic heuristics, to the hybridizations between metaheuristics. All this thanks to the technological advances of computers that allow us to solve increasingly complex problems, as seen in figure 2.

The use of metaheuristics techniques, as shown in Table 2 have been preferably used due largely to its great advantage over the exact techniques to find good solutions in reasonable times of execution [67].

The most recent in the field of metaheuristics is the use of hybridizations. Which bases its interest in improving the performance of the final algorithm by combining the best individual characteristics of its predecessors mitigating the opposite effects of being hybridized [68], [69].

Some applications of these techniques in transport models can be found in [70], which use a PSO (Particle Swarm Optimization) hybridized with a Variable Neighborhood Search algorithm to strengthen its level of intensification. As mentioned by the authors to solve a Vehicle Routing Problem with Simultaneous Pickup and Delivery; otherapplication related to this kind of problems will be founded in [71] and [72].

Related to the subject of consolidations, it is possible to find the following applications:
Hosseini et al. (2014), perform an application that mixes the problem of consolidation of the product with the one of the routing of vehicles. The former solves it by means of the use of matrices that give the state of the warehouses and clients in terms of capacity and requirements; and the second, through the hybridization between a simulated annealing algorithm and a harmonic algorithm.
Du et al. (2007) propose the use of experiment design to develop scenarios to test the Milk Run system and select the best alternative for a real-time system.

Arvidsson (2013) reviews the impact of scheduled deliveries through the milk-run system on the environment and the economy; Arguing that in urban areas an average of between 20-30% of the vehicles that circulate are vehicles of load, contributing between 16% up to 50% in the emissions of CO_2 released to the atmosphere.

Hasani and Hessameddin (2016) apply a PSO algorithm to locate their cross-docks as close to their customers as possible to minimize the distances between them and the nearest delivery point.

Kuo et al. (2016) mention that a warehousing management policy is a crucial issue in logistic management. It must be managed effectively and efficiently to reduce the production cost as well as the customer satisfaction. A synchronized zoning system is a warehousing management policy, which aims to increase the warehouse utilization and customer satisfaction by reducing the customer waiting time. For that reason, they apply a particle swarm optimization to assign the products that will be collected by the client at a certain point in the network.

Based on the above, [77] mentions that in his bibliographical revision to the area of logistics in the auto parts sector, there are few applications that consider real cases and involve more complex problems to solve; without omitting significant variables for the process.

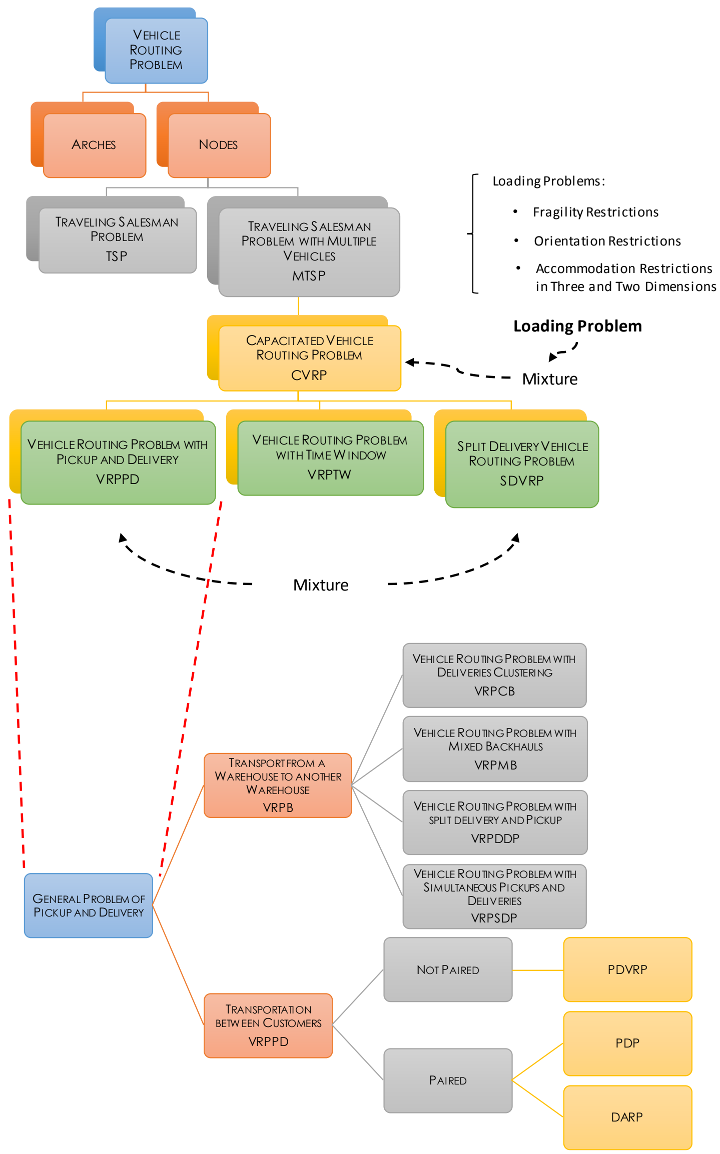

Fig. 1. Schematic classification of the different transport models; based on [25], [26] and [27]

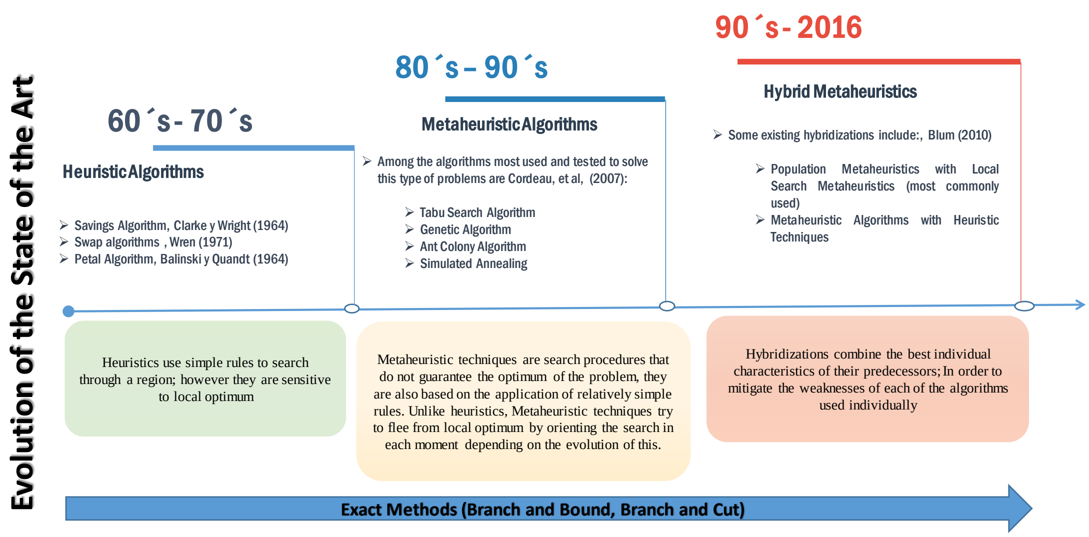

Fig. 2 Solution techniques evolution, based on [27] and [65]

Conclusions

Through state of the art previously shown, it can be concluded that due to the high complexity of the supply chain of the automotive industry, the different modes of consolidation and their possible mixtures can generate quite complex transport models that will be sometimes unique and can be only applied to a single company. without being able to reach a generalization.

In the analysis, the importance of the metaheuristic algorithms and their great contribution in the resolution of the transport models present in any industrial sector is observed. However, each time the solution methods seek to reflect more the reality that surrounds them trying to represent this reality through mathematical models; which can become multi-layer or multiplex networks, designed to model complex systems with their respective characteristics. Boysen et al. (2015), however, identifies the lack of real applications in the automotive sector of many of these models.

All this generates that some suppliers can be deprived of this system of collection; Forcing them to identify their transport models and optimize their distribution network.

However, the system is so complex that in many cases the traditional methods of solution are short in the face of the great demands of real problems. This has generated that these models evolve through the time, integrating more detail. Which increases the processing times for these, generating greater interest in heuristic techniques that offer good results in reasonable times of solution for a correct decision-making?

With the above mentioned, the reader is encouraged to interfere in the methodologies of complex systems in order to increase the levels of detail of the models and reduce the variability between these and reality.

Acknowledgments

I am grateful for the support to CONACYT for making this work possible; Likewise, I greatly thank my tutor Dr. Idalia Flores de la Mota whom I greatly esteem.

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