VMI-type Supply Chains: a Brief Review

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Received 12 September, 2012; Revised 29 February, 2013; Accepted 20 April, 2013

Abstract

The primary purpose of this paper is to highlight, for the research community and practitioners, the various aspects of using VMI-type supply chains in today's business environment as well as a number of directions for future studies. In this regard, fifty articles published in major international journals, beginning in 1995, which contribute to the VMI-type supply chains are reviewed via a systematic review methodology. Our findings show there is an incremental growth in employing of VMI strategies in logistic and supply chains. This paper characterizes the design aspects required to configure and establish a VMI-type supply chain in the industry including demand pattern, number of products, contract type between two parties, and profit sharing scheme. Moreover, the current gaps in the current state of VMI-type supply chain in literature are highlighted in the last section of this paper that may motivate future studies.

Keywords: vendor-managed inventory, contract, supply chain, inventory.

1. Introduction

When, as customers, we were negotiating an outsourcing managed service contract in IT telecommunication industry with an international vendor, we asked ourselves "could it be possible to take the same concept of managed service in other fields of business such as operation management?"

To find the answer, we started searching through the web and scientific resources to obtain some background in this type of contract. Exploration of resources using the main keyword of "vendor managed service" led us to find the interesting concept of Vendor Managed Inventory (VMI) in the area of supply chain management.

According to Mattson (2000), a supply chain is a physical network in which different entities of material, cash and information are transferred amongst the players. At the start of the chain, there is some kind of supplier providing raw material and the chain ends with the customer consuming what has been produced. The material typically flows in a downstream direction and cash in the opposite, whereas information flows in both directions. In other words, supply chain management is an integrative approach dealing with the planning and control of materials and information from suppliers to end customers (Monczaka et al., 1998; Jones and Riley, 1985)

Since, a key issue in supply chain management is how to encourage all parties to cooperate and coordinate their decisions and activities in order to optimize the system-wide performance (Li and Wang, 2007; Sarmah et al., 2006), various collaboration, coordination and cooperation strategies have been used in new supply chains to overcome such an issue. Yu (2009) believes that cooperation and coordination between enterprises can bring great benefits to supply chains. Therefore, the emphasis on supply-chain coordination has increased in recent years (e.g., see Arntzen et al. 1995; Lee and Billington, 1992; Lee et al., 1997; Tayur et al., 1999). According to Zhao (2010), cooperative relations are increasingly becoming prevalent in today's supply chains. There are many possible interactive coordination mechanisms that can occur between two members of supply chain including seller and buyer. Various types of mechanisms have been discussed in the literature on supply chain coordination such as quantity discount, credit option, buy back or return policies, quantity flexibility and commitment of purchase quantity (Sarmah et al., 2006). Cachon (2003) reviews the literature on supply chain coordination with contracts. Moreover, a survey conducted by Tyana and Wee (2003) points out that aside from the computer technologies, the key to implementing VMI lies in the abilities of the related chain members to cooperate and to understand the flows and processes concerning their products or services delivery.

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Moreover, coordinating supply chain is an effective way to improve channel performance (Kim and Park, 2010; Wong, 2009).
Although, VMI was initiated in the mid 80's following the partnership between Wal-Mart and Procter & Gamble, but the basic concepts were provided in 1958 by John F. Magee (Vigtil, 2013). Wang (2010) believes that VMI has received much more attention today and its implementation has led to successful collaborative efforts in supply chain integration. Almehdawe and Mantin (2010) refer to the recent developments in information technology which have facilitated the emergence of new cooperative supply chain contracts such as VMI. Yu and Huang (2010) describe VMI as an inventory cooperation scheme in supply chains. In traditional supply chains, each player takes the responsibility to manage his own inventory, and production and distribution activities. Also, a member has only the feasibility to control the information of his adjacent agent. In this traditional context, lack of coordination is common amongst the players. In VMI-type supply chain, the vendor shall take broader responsibility in inventory management that may lead to taking care of buyer's inventory as well.
Prior to the emergence of VMI, a number of other collaborative models such as Quick Response (QR), Continuous Replenishment Programs (CRP), Efficient Consumer Response (ECR), and Collaborative Planning, Forecasting and Replenishment (CPFR) were dominant focusing on efficient replenishment.
The purpose of this paper is to thoroughly review VMI-type supply chains from multiple perspectives. The main issues to address include: what are the major solution models and techniques proposed by previous researchers to solve VMI-type supply chains? What types of demands have been addressed? What are the main applications of such types of supply chains in the world-wide practices? What contract types have been used as an agreement between the members?

2. Materials and Methods

Since the relevant literature on VMI-supply chain has been dispersed in various publications, we had to search out most of the journals to find out enough materials leading us to compose an appropriate review paper in this filed. In this regard, we also tried to synthesize most of previous findings by other researchers. According to Fig.1, approximately, 106 papers were identified as a result of our searching. In the first step, these papers were quickly reviewed to eliminate those papers that were not directly relevant to our research. In this regard, the relevant conference papers, doctoral dissertations, book chapters and published reports were also included. As a result, about half of the papers were selected for a more in-depth review process. Thereupon, each selected paper was carefully studied from different angles discussed in this study. The main dimensions and attributes which helped us to review the paper and extract the key findings are: the used algorithm as the solution, types of variables (e.g. fuzzy), no. of echelons and no. of players in each level which reflect the complexity of SC system, model's objectives (e.g. profit maximization), and contract types in VMI partnership.
Based on about 68 papers thoroughly reviewed, it can be seen that most of these papers are only published in 13 international journals. Further, the majority of them are published in 4 main journals. Fig.2 shows the related statistics that can be used as a reference for future studies.

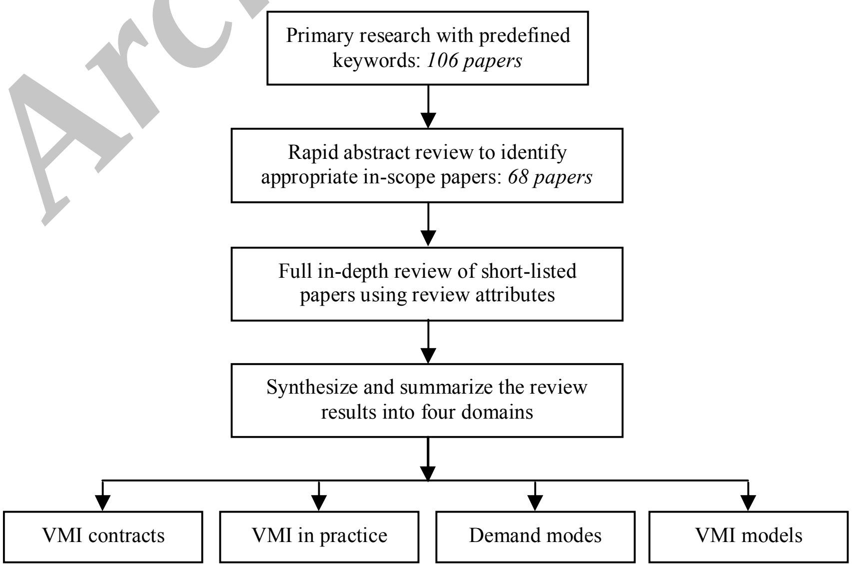

Fig. 1. Research methodology in our review process

A variety of definitions concerning VMI can be found in the literature. Table 1 shows a summary of available definitions on VMI during 1995-2014. VMI is mostly addressed as an arrangement, configuration, strategy, system, and a coordination or cooperation scheme in supply chain. Based on the provided definition on VMI, we find it more suitable to call VMI as a new constructive business model in supply chains. Indeed, VMI is mainly considered as a coordination scheme in which vendor takes the responsibility of overall management of inventories while both vendor and retailers seeks to integrate their inter-related operations. Based on the literature, this strategy concentrates on the following objectives:

- to reduce inventory management costs
- to orchestrate replenishment cycles
- to promptly respond to market needs
- to reduce the bullwhip effects
- to improve customer service

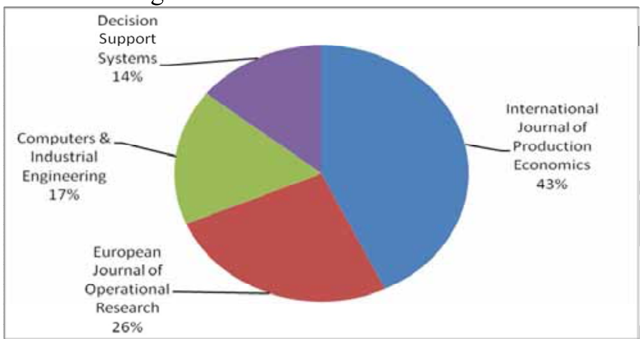

Fig. 2. Frequency (%) of published papers in four main int. journals

Table 1
VMI definitions

Year	Author(s)	Definition
1995	ECR Best Practices Operating Committee	is an efficient replenishment practice designed to enable the vendor to respond to demand without the distortive effect of purchasing decisions in the retail chain
2000	Cetinkaya and Yee Lee	an important coordination initiative.
2001	Dong and Xu	is an effective supply chain strategy that can realize many of the benefits obtainable only in a fully integrated supply chain
2002	Tyan and Wee	sometimes called vendor-managed replenishment, is a ‘pull’ replenishing practice designed to enable a Quick Response (QR) from the vendor to actual demand.
2003	Disney and Towill	is a supply chain strategy where the vendor or supplier is given the responsibility of managing the customer’s stock.
2003	Disney and Towill	is one practical way of seeking to obtain the benefits of echelon elimination
2003	Kuk	is a tool used to improve customer service and reduce inventory cost
2005	Yao et al.	is a collaborative commerce initiative where suppliers are authorized to manage the buyer’s inventory of stock-keeping units.
2007	Yu et al.	is an inventory management strategy to let a vendor manage his retailers’ inventories, which makes the vendor have the opportunity to obtain some inventory and market-related information of his retailers.
2008	Al-Ameri et al.	is a system where vendors (suppliers) take the responsibility of managing their customers’ inventory at customers’ sites.
2008	Southard and Swenseth	as an inventory and supply chain management tool in which the supplier has taken the responsibility for making decisions as to the timing and amounts of inventory replenishment.
2009	Wong et al.	is an important flow coordination scheme which integrates operations between suppliers and retailers through information sharing and business process reengineering.
2009	Yao	is a partnership between a supplier (often a manufacturer) and a customer (described here as a distributor) whereby the supplying organization makes inventory replenishment decisions on behalf of the customer.
2009	Darwish and Odah	is an integrated approach for retailer–vendor coordination, according to which the vendor decides on the appropriate inventory levels within bounds that are agreed upon in a contractual agreement between vendor and retailers.
2009	Yu et al.	is one of the widely used strategies for achieving system integration in the arena of supply chain management. The VMI model is a channel coordination strategy between downstream and upstream players.
2010	Yu and Haung	is an inventory cooperation scheme in supply chains.
2011	Kim and Park	is a supply chain arrangement, where coordination between vendor and retailer is an essential part.
2011	Campuzano and Mula	is a supply chain configuration where the end consumer’s sales and the customer’s inventory level are known by the supplier to set production and distribution objectives.
2012	Chen et al.	is an effective way of reducing the bullwhip effect in real-world supply chains.
2013	Sadeghi et al.	is a policy in supply chain management (SCM) to reduce bullwhip effects.
2014	Sadeghi et al.	in the VMI model, there is a cooperation between vendor and retailers to determine the inventory level.

In addition, our analysis of local publications in Iran shows that there are only two MSc theses that focus on the concept of VMI supply chain. In the first research, Mehdipour (2008) examines the requirements of a VMI system in an automotive industry. The goal is to study the readiness level of the mentioned automaker to see if it has enough potential to establish a VMI partnership for its big and complicated supply chain system. He utilized a set of questionnaires and statistical tools to interpret his findings. In addition, Soufifard (2006) also provides a comparative assessment between VMI supply chain and the conventional inventory management. Our study shows, the subject is too young both among academics and practitioners; this requires additional attention and consideration.

3. Results and Discussion

3.1 The application of different models in VMI-type supply chains

In this section, we examine the VMI models based on three major dimensions: number of products (single or multiple), number of echelons (two or three), and the applied solution algorithm. The papers discussing VMI strategy in supply chains are mostly published during 1998-2014. More than 90% of those papers have addressed single product models while the remaining 10% such as the works done by Yu and Huang (2010) and Pasandideh, et al., (2011) investigated multi-product models. Indeed, Yu and Huang (2010) studied a product family including multiple types of substitutable products. Also in the second research, the authors proposed a multi-product EOQ model.

Focusing on the number of echelons or levels considered in the literature, it is clear that the preference for most of the current researchers is to propose their models for a simple two echelon supply chains. In this regard, only there are three papers respectively published by Yu et al. (2009), Arora et al. (2010) and Yu and Huang (2010) in which a three-echelon supply chain was studied. Even in these cases and as expected, the VMI relationship is obviously agreed between two partners of supply chain such as manufacturer and retailer.

Finally, with respect to the applied solution algorithm, there are eight types of popular models in solving VMI-type supply chains as per listed below:

- analytical
- operation research or mathematical (e.g. nonlinear programming)
- system dynamics
- simulation
- game theory (e.g. stackelberg)
- meta-heuristic (e.g. ant colony optimization)
- regression
- hybrid (e.g. hybrid PSO or combination of game theory with GA)

Yeon Lee and Ren (2011) presented a periodic-review stochastic inventory model to examine the benefits of VMI from economies of scale in production/delivery in a global environment characterized by exchange rate uncertainty and large fixed costs of delivery. According to the results, they believe that the retailer always benefits from VMI while the supplier is better off under VMI when his fixed ordering cost is much larger than that of the retailer. In the numerical examples in this paper, it is clear that the supply chain total cost always decreases under VMI. Pasandideh et al. (2011) studied a two-level supply chain consisting of a single supplier and a single retailer that operates under VMI system. They formulated the problem as a non-linear integer-programming (NIP) model and proposed a genetic algorithm to solve it. The objective was to find the order quantities and the maximum backorder levels such that the total inventory cost of the supply chain is minimized. They also proposed interesting areas which can be utilized for future researches in the conclusion section. In another study conducted by Liao et al. (2011), a Multi-Objective Location–Inventory Problem (MOLIP) is proposed to model a VMI supply chain. This model is then solved with a hybrid evolutionary algorithm which is preliminarily based on a well-known NAGA-II evolutionary algorithm with an elitism strategy and a non-dominated sorting mechanism. To show the efficiency of this algorithm on VMI-type supply chains, they performed computational experiments and compared in with the results obtained from a well-known multi-objective evolutionary algorithm. The results conclude that such a model has enough potential to be approached for solving difficult problems. As an instance of learning adoption in VMI-type supply chain we can address the study done by Zanoni et al. (2012) who showed the effect of learning and forgetting functions in the vendor's production process under a VMI with consignment agreement. In this paper, five shipment policies were also investigated so as to help top management to better utilize capacity, improve the management of inventories, and coordinate production and distribution throughout the supply chain under a VMI with consignment business practice. Besides, in the other study by Shu et al. (2012), a logistics network design problem with vendor managed inventory is studied. The model is formulated as a set-packing problem and solved using branch and price. The model assumed to be an integer programming problem. In this problem, the supplier experiences the retailer having serving flexibility over the traditional model that requires all the demands should be served. Chen et al. (2012) provides an explicit treatment and insight into the vendor's optimal distribution policy with transshipment under the VMI environment. They also discuss how transshipment and demand variability interact with the vendor's decision making. In fact, they show that any correlation between demand distributions of retailers will impact the vendor's optimal distribution policy with transshipment. Kristianto et al. (2012) extended the functionality of the VMI model by developing an adaptive fuzzy smoothing constant. In this paper, the bullwhip effect has been reduced by the application of adaptive fuzzy VMI control. They used GoldSim to simulate the proposed model and evaluate the bullwhip effect in both traditional and GA-based fuzzy VMI control policy. Kastsian and Monnigmann (2012) address optimization of a VMI problem using normal vector method. This method is based on bifurcation theory and nonlinear programming. In contrast to the previous approaches, where economic and dynamical properties were combined into one multi-objective function, in this method, economic optimality is treated in the objective functions, while desired dynamical properties, such as guaranteed stability, are addressed by augmenting the optimization problem with appropriate constraints. In addition, one of the recent papers that proposed a new heuristic algorithm is the work done by Cárdenas-Barrón et al. in 2012. They mainly address the previous paper published by Pasandideh et al. (2011) and expand their work with the proposition of a novel heuristic algorithm in comparison to GA to solve a VMI system with multi-product, multi-constraint based on EOQ with backorders considering two classical backorders costs: linear and fixed. They found that the heuristic algorithm performs better result on all test problems. Sue-Ann et al. (2012) also proposed a particle swarm optimization (PSO) and hybrid GA and artificial immune system (GA-AIS) to find out optimum parameters of a two echelon single vendor multiple buyers VMI problem. These parameters include: sales quantity and sales price. They compared the obtained result against LINGO, DX, and GA models which are available in the literature. Among these models, PSO provide much better results.

Considering deteriorating products, Yu et al. (2012) discussed a VMI problem where both the raw material and the finished products are subject to deterioration. Note that the deteriorating rates are all known constant and retailers' demands are deterministic. The goal is to find the optimal quantities for the decision variables of common replenishment cycle for the finished product and the replenishment frequency for the raw material. An exact algorithm is presented to solve such problem and determine the optimal policy.

Shu et al. (2012) brings into attention the two concepts of integrated logistics network design optimization and VMI supply chain in their research. The model is formulated as a set-packing model and solved using branch-and-price. The retailers face a deterministic demand. They compare the efficiency of their model against a traditional sequential decision-making model. The average benefit ranges from 10.4% to 21.7% in terms of the total profit.

Hariga and Al-Ahmari (2013) address a consignment VMI partnership model where the supplier is responsible for initiating orders on behalf of the retailer and decides about the size of each order, the quantity to be displayed on the shelves, and the reorder point. A mathematical model along with some sensitivity analyses are provided to show the advantages of such consignment agreement. As an interesting result, they found that when the retailer does not restrict the shelf space capacity, it is more economical for the supplier to display directly the ordering quantity on the shelves without temporarily storing it in the retailer backroom facility. The ant colony optimization (ACO) is another meta-heuristic algorithm used to solve a VMI-type supply chain. Roozbeh Nia et al. (2013) employed this algorithm to find a near-optimum solution of the fuzzy nonlinear integer-programming problem with the objective of minimizing the total cost of the VMI supply chain. To demonstrate the applicability of this algorithm to such problems, they have to develop a genetic algorithm and a differential evolution solution for the same problem to validate the obtained result of ACO. Yu et al. (2013) study the issue of optimal selection of retailers in a VMI problem using a Stackelberg game. Since they need to solve a non-linear, mixed-integer, game-theoretic, and analytically intractable model, they propose a hybrid algorithm that combines the concepts of dynamic programming, GA, and analytical methods. With focus on maximizing the manufacturer's profit, the presented hybrid algorithm only takes less than one minute for solving a problem with 100 retailers while the same problem with 20 retailers will take more than hours for the case we want to use GA algorithm. Hariga et al. (2013) consider a VMI supply chain where a vendor supplies a single item to multiple retailers under a VMI agreement. By this agreement, the retailers specify their maximum allowed inventory levels. A mixed integer non-linear model that allows unequal replenishment intervals is developed so as to minimize the joint relevant inventory costs under storage restrictions. To solve the problem, a cost efficient heuristic algorithm is also proposed. The authors revealed that greater cost-saving happens in the case of increased variability in retailers' demand and cost parameters while they use heuristic method. Sadeghi et al. (2013) address a special case of VMI supply chain which has been rarely discussed in the literature. They focus on a multi-vendor multi-retailer single-warehouse (MV-MR-SW) supply chain that has not been investigated yet. The aim of this paper is to find the number of shipments received by retailers and vendors and to determine order quantities so that the total inventory cost of the chain is minimized. For such an integer non-linear programming problem, two meta-heuristic algorithms of PSO and GA are proposed while their parameters are also tuned by Taguchi method. Various problems are presented to compare the effectiveness of each algorithm. The results indicate that the hybrid PSO provides better performance. Since the context of their algorithm is a deterministic environment, they suggest other researchers to apply uncertain environment for their future research. They also advise taking other meta-heuristic into play as of further directions in this area. Tu Chen (2013) examines the dynamic performance of vertically decentralized two-echelon channel coordination for deteriorating goods under consignment and vendor-managed inventory (VMI) contracts with revenue sharing from retailer-centric business-to-business transactions in both traditional markets and electronic markets (EMs). In the most recent paper presented by Sadeghi et al. (2014), a multi-objective combinatorial optimization model of a supply chain problem including one-vendor multi-retailers considering a VMI approach is studied. Indeed, the previous work by Zavanella and Zanoni (2009) is extended to include both the transportation cost and the redundancy allocation of production machines. They aimed to find the order size, the replenishment frequency of the retailers, the optimal traveling tour from the vendor to retailers, and the number of machines so as to minimize the total chain cost while the system reliability of producing the item is being maximized. For such problems, a meta-heuristic optimization algorithm of non-dominated sorting genetic algorithm-II (NSGA-II) is proposed as a solution. Besides, a non-dominated ranking genetic algorithm (NRGA) is suggested to solve the problem as well while letting them compare both solutions in terms of performance measures.

Table 2 shows the references for the aforementioned models and algorithms. In addition, other uncommon models such as retrospective action-reward learning model provided by Kuk (2004) and a near saturated search technique (Yao and Dresner, 2008) are respectively used by Kwak et al. (2009) and Disney and Towill (2002). In addition, Hariga et al. (2013) proposed a specific and cost-efficient heuristic algorithm is proposed.

Since 2009, the interest in utilizing game theories in both modes of cooperative and non-cooperative has increased in VMI supply chains. For instance, Yu et al. (2009), and Chen et al. (2010) used the non-cooperative Stackelberg game in their models. Yu et al. (2009) utilized evolutionary game theory to analyze the evolutionary stable strategy of the VMI supply chains to examine the intrinsic evolutionary mechanism of the VMI method. Yu and Huang (2010) proposed a dual non-cooperative Nash game which is composed of two sub games. Our study shows a few other game modes such as differential games, repeated games, signaling, and screening games are also partially discussed in VMI. Kim and Park (2010) employed a differential game model to formulate the VMI supply chain in an analytical way. They put the game theory as a basis for the system dynamics modeling. Using the real data for 8M-pixel digital cameras, they evaluated the game model as a numerical example. Almehdawe and Mantin (2010) consider a Stackelberg game vendor managed inventory framework in two scenarios where in the first scenario the manufacturer is leader and in the second one, one of the retailers act as a dominant leader. They formulated the game concept in a VMI supply chain consisting of a single manufacturer and multiple retailers.

Table 2
Classification of solution models in VMI-supply chains

Author (year)	Model
Cetinkaya and Lee (2000) Kuk (2007) Yao and Dresner (2008)	Analytic model
Achabal, et al. (2000) Hariga and Al-Ahmari (2013)	OR/mathematical model
Kim and Park (2011) Ovallea and Marquez (2003)	System dynamics and/or Game theory
Towill and Disney (2003) Southard and Swenseth (2008)	Simulation model
Yu (2009) Yu, et al. (2009) Chen, et al. (2010) Yu and Huang (2010) Almehdawe and Mantin (2010)	Game theory
Arora, et al. (2010) Roozbeh Nia et al. (2013)	Dynamic ant colony optimization model/ ant colony optimization (ACO)
Nachiappan and Jawahar (2007) Lin (2010) Liao et al. (2011) Pasandideh, et al.(2011) Kristianto et al. (2012) Cárdenas-Barrón et al. (2012) Sadeghi et al. (2013) Sadeghi et al. (2014)	Meta-heuristic (GA, PSO)
Yao (2010)	Regression model
Sue-Ann et al. (2012) Yu et al. (2013)	Hybrid (PSO and hybrid GA, GA-AIS, Dynamic programming, GA, and analytical methods)

Stackelberg game framework has also been used by other previous works to coordinate the relationships and decisions in supply chains. On the other hand, utilization of game theory enables researchers to investigate the leadership in supply chain arrangements. In addition, Yu et al. (2009) adopt studying of Stackelberg game problem in a VMI supply chain where advertising, pricing, and inventory replenishments (for both finished products and multiple raw materials) are all involved. In this problem, the manufacturer is the leader and retailers are followers. A computational algorithm has been proposed to solve this game model based on the theoretical analysis of the best response functions with a generic demand function. Yu et al. (2009) also used evolutionary game theory to study the evolutionary stability of the VMI strategy. Based on Table 2, meta-heuristic methods are of the most popular solutions to resolve VMI models. Indeed, GA, ACO, and nowadays PSO individually or in a hybrid context in recent years.

From the obtained results of our review, we can summarize the following shortages in the current literature of VMI modeling which can be treated as extra dimensions for future studies:

- Non-deterministic and fuzzy condition for demand and model's parameters needs to be considered.

Currently most of the reviewed studies have focused on deterministic models.

- Although, multi echelon SC such as multi-vendors, multi retailers are studies as well, but it seems in contrast to other combination models, they are too few.
- Lack of soft-computing and artificial intelligence techniques in VMI supply chains are clear. Based on Ko et al., Genetic algorithm (GA), Fuzzy logic (FL), Neural network (NN), and Expert system (ES) are of the most frequent soft computing techniques that has been used in the area of supply chain management. GA and somewhat FL is the most frequent technique that has been used in solving VMI-type supply chain. The others have never been used in VMI.
- Despite proposition of a few papers that concentrate on dynamic modeling of VMI, the topic still needs to be addressed by dynamic modeling such as system dynamics.
- Other meta-heuristic algorithms such as simulated annealing (SA) and imperialist competitive algorithm (ICA), bat algorithms (BAs), and the estimation of distribution algorithms (EDAs) with their comparison with already and frequently discussed meta-heuristic algorithms such as GA, PSO, and ACO shall be brought to attention.
- Instead of EOQ model in some cases, economic production quantity (EPQ) model can be also discussed.
- Other contract types such as buy-back, quantity discount pricing, two-part tariff and backup agreement needs to be studied by researchers. Section 3.4 discusses the contract types in VMI partnership.
- The shortage, discount, and risk parameters need to be considered in VMI modeling.
- The issues of multiple vendors and multiple retailers in competition mode are of the other orientation which currently neglected in existing literature. There are only too few papers that paid attention to the concept of competition between retailers.

3.2 Demand models in VMI

The type of demand in VMI-supply chains is a very critical parameter differentiating one VMI model from the others. Our study shows four types of demand patterns are available in the literature including:

- deterministic or integer;
- stochastic/random;
- variable; and
- fuzzy.

Table 3 lists the papers concentrate on different demand types mentioned above. Deterministic and stochastic customer demand patterns are typically used in the literature.

Table 3
Demand types in VMI supply chains

Demand	Ref.
Deterministic/ Integer	Sadeghi et al. (2014); Sadeghi et al. (2013); Hariga et al. (2013); Zanoni et al. (2012); Shu et al. (2012); Yu et al. (2012); Pasandideh et al. (2011); Darwish, and Odah, 2010; Kim and Park, 2010; Almehdawe and Mantin, 2010; Yu and Huang, 2010; Towill and Disney, 2003; Yao, 2007; Yu, et al., 2009; Chen, et al., 2010; Zhang, 2007; Gumus, 2008; Yu, 2009; Nachiappan and Jawahar, 2007
Stochastic/Random	Kastsian and Monnigmann (2011); Cetinkaya and Lee, 2000; Wong, 2009; Yao, 2010; Arora, et al., 2010; Yao, and Dresner, 2008; Achabal. et al., 2000
Variable	Liao et al. (2011); Southard and Swenseth, 2008; Kwak, et al., 2009; Yu, et al., 2009; Hu, 2008; van der Vlist, et al., 2007
Fuzzy	Roozbeh Nia et al. (2013)

On the other hand, with respect to the demand pattern in the existing research, the demand follows a Bass diffusion model in the paper provided by Kim and Park (2010). Additionally, the Cobb-Douglas demand function has also been used in many studies conducted by Yu et al. (2009a), Yu et al. (2009b), and Almehdawe and Mantin (2010). As summarized in Table 3, most of the studies are focusing on deterministic demands while the fuzzy demand is only discussed in one of the papers of the portfolio we reviewed. Indeed, many publications propose fuzzy demands as a line for future research.

3.3 VMI in practice

In this section, we review some of the most prominent applications of VMI strategies in practice. Achabal et al. (2000) describe how a VMI decision support system was implemented for an apparel manufacture with over 30 of its retailers leading to improvement of the services levels significantly. Southard and Swenseth (2008) proposed an evaluation of VMI model using the data collected from two agricultural cooperatives in Nebraska. This data includes farm fuel delivery dates and amounts for 277 customers over a 2-years period. Using these data, demand was simulated in their model. In the next study, Kim and Park (2010) used the sales data of the 8M-pixel digital cameras sold in Japan during Jan. 2006 to Dec. 2008 for their analysis on a real environment. Indeed, they tried to show the dynamic relationships and interactions among decision variables in a VMI setting based on the reality. The two main findings of this case study were: the better combined profit for both manufacturer and retailer and less fluctuation in inventory level while the flexible pricing strategy is in place.

Besides, Tyan and Wee (2002) discussed a VMI agreement in a two echelon supply chain model to show the practical implementation of such scenarios in the Taiwanese grocery industry. They believe in slowness of VMI growth in Taiwan industries in comparison with western companies. Based on one analytical report by Coopers & Lybrand Management on Taiwan's grocery industry in 1998, they were dealing with challenging issues such as keeping high pipeline inventories compared with the rest of world and unprecedented market competition while they open their market to foreign companies. A VMI program was initiated in Taiwan's retail industry by government in the same year. In this regard, Wellcome group and P&G started to commonly deploy a VMI partnership together. Following the successful implementation of VMI program in the mentioned company, some progress were achieved including the decrease in pipeline inventory, less data override, and billing accuracy.

The benefits of VMI-strategy are also successfully recognized by other well-known companies such as Wal-Mart, Fruit of the Loom, Shell Chemical, Kmart, Dillard Department Stores, JCPenney, Lucent Technologies, Electrolux Italia, Dell, HP, ST Microelectronics, Target, Walgreens, Barnes & Nobel, Eckerd, and Procter & Gamble (Holmstro, 1998; Towill and Disney, 2003; Hu, 2008; Gurenius and Wicander, 2007; Tyana and Wee, 2003; Ronen, et al., 1987; Miller, 1987; Sadeghi et al., 2014; Chen et al., 2012; Pasandideh et al., 2011; Hariga and Al-Ameri, 2013; Yu et al., 2013; Shu et al., 2012; Tu-Chen, 2013). One of the interesting facts to us was the successful implementation of VMI in many famous companies which is increasingly growing these days. Some examples are Wal-Mart (Jones and Riley, 1985; Darwish and Odah, 2010; Cetinkaya and Lee, 2000; Towill and Disney, 2003; Achabal, et al., 2000; Nachiappan and Jawahar, 2007; Killingworth, 2011; Gurenius and Wicander, 2007; Paulitsch, 2003; Zhang, 2008; Christiansen, et al., 2004; Zhao, 2010; Disney, et al., 2003), Fruit of the Loom (Gurenius and Wicander, 2007), Shell Chemical (Gurenius and Wicander, 2007; Jones and Riley, 1985), Kmart and Dillard Department Stores (Towill and Disney, 2003), JCPenney (Towill and Disney, 2003; Wang, et al., 2009; Zhao, 2010), Lucent Technologies (Towill and Disney, 2003), Electrolux Italia (Ronen, et al., 1987), Taiwanese grocery industry (Tyana and Wee, 2003), Dell and HP (Wong, 2009; Tyana and Wee, 2003; Yao, 2010; Paulitsch, 2003), ST Microelectronics (Yu, 2009; Tyana and Wee, 2003; Yu, et al., 2009), Barilla (Yu, 2009; Wong, 2009; Achabal, et al., 2000), Target, Walgreens, Bares & Nobel, and Eckerd (Hu, 2008), Procter & Gamble (Holmstro, 1998; Yao, 2010; Achabal, et al., 2000; Paulitsch, 2003; Jones and Riley, 1985; Cetinkaya and Lee, 2000), Campbell Soup and Johnson & Johnson (Achabal, et al., 2000; Jones and Riley, 1985). Also, Kauremaa et al., (2009) studied five VMI cases to investigate the type of benefit acquired by both suppliers and buyers. Using a cross-case study approach, they also evaluated the revenue-sharing model between suppliers and buyers. Govindan and Nicoleta Popiuc (2011) present an overview of coordination contracts within forward and backward supply chains. They also summarized the applicability of coordination contracts in different areas and industries.

Table 4 summarizes the applicability of VMI-type supply chains in various industries in the world. It is clear that VMI popularity is still increasing in retailing industry. Besides, high-tech companies like HP, Dell and ST Microelectronics in computer and electronic have also preferred to implement this policy to reduce their inventory costs.

Table 4
VMI practice in industries

Industry	Example
Apparel	Fruit of the Loom
Computer/Electronics	HP, Dell, ST Microelectronics
Consumer goods	Procter & Gamble
Food processing	Campbell Soup
Home Appliances	Electrolux Italia
Medical equipment/ Pharmaceutical	Johnson & Johnson
Petrochemicals	Shell Chemical
Retailing	Wal-Mart
	Kmart
	Dillard Department Stores
	JCPenny (Clothes)
	Target
	Walgreens (Drug)
	Barnes & Nobel (Bookseller)
	Eckerd (Drug)
Telecommunications equipment	Lucent Technologies

3.4 VMI contracts

According to Tsay (1999), the supply chain contract is "a coordination mechanism that provides incentives to all of its members so that the decentralized supply chain behaves nearly or exactly the same as the integrated one". Our review shows that there are only very limited use of agreements, contracts or protocols between the players in the majority of VMI-type supply chains discussed in the literature. Merely, sales rebate contract (Vigtil, 2003), incentive contract (Achabal, et al., 2000) and explicitly incorporated contract Jones and Riley, 1985) have been addressed amongst the papers reviewed model in this study. VMI supply chains are normally characterized by the existence of a protocol, an agreement or a contract between the players. The presence of a contract mainly represents the responsibility of each member on inventory management and specifies how to share the revenues and risks in the supply chain. Table 5 shows different types of contract available in the literature along with their definitions. Cachon (2003) did a detailed investigation on different contract types established in simple or complex supply chains. He studied a number of contracts including buy backs, revenue sharing, quantity flexibility and sales-rebate to coordinate the newsvendor supply chain model. He shows how these contracts behave differently.

Table 5
Contract types in VMI supply chains

Type	Description
Buy-back	The buyer is allowed to return any leftover units to the supplier at the end of the period at a fraction of purchase price (Govindan and Nicoleta Popiuc, 2011). The manufacturer specifies a wholesale price and a buyback price at which to purchase unsold units at the end of the season (Mahajan, 2010). In such a contract, the manufacturer agrees to buy back unsold goods from the retailer for some agreed-upon price. (Boute and Lambrecht, 2007)
Revenue-sharing/ shared savings	The supplier initially charges the buyer a low wholesale price at the beginning of period and the buyer shares a fraction of the revenue generated from the sales at the end of period (Govindan and Nicoleta Popiuc, 2011). The RS contract is a coordination mechanism offered by the distributor to the retailer, which modifies the retailer's profit (and also the distributor's one) so as to incentive her to make decisions coherent with the SC total optimization (Giannoccaro and Pontrandolfo, 2004). With a revenue-sharing contract a retailer pays a supplier a wholesale price for each unit purchased plus a percentage of the revenue the retailer generates (Cachon and Lariviere, 2001). In a revenue sharing contract, the manufacturer shares a fraction of the revenue of the retailer and offers the retailer a low wholesale price (Towill and Disney 2003). This contract is also called "Shared-savings" in the paper by Cachon (2003).
Consignment	Under such a contract, ownership of the goods is retained by the supplier and price is also usually determined solely by the supplier. For each item sold, the retailer will deduct an agreed percentage from the selling price, remit the balance to the vendor and no money changes hands until the item is sold (Li, et al., 2009).
Wholesale price	The manufacturer charges the retailer W per unit purchased (Hu., 2008).
Quantity flexibility	The buyer is allowed to modify the order within limits agreed to the supplier as demand visibility increases closer to the point of sale. The buyer modifies the order as he gains better idea of actual market demand over time (Govindan and Nicoleta Popiuc, 2011). the manufacturer provides an "upside" coverage to the retailer of u% above the initial order. In return, the retailer accepts a "downside" commitment of d%. The retailer commits him/herself to a minimum purchase requirement. The retailer is allowed to cancel d % of the order but must take the remainder. (Boute and Lambrecht, 2007)
Quantity discount pricing	This resembles to the sales rebate contract, but there is no threshold defined, but the customer pays a wholesale price inversely proportional to the order quantity (Egri, 2008).
Two-part tariff (a subset of wholesale contract)	In this case the customer pays not only for the purchased goods, but in addition a fixed amount called franchise fee per order. This is intended to compensate the supplier for his fixed setup cost (Egri, 2008).
Backup agreement (a subset of quantity flexibility contract)	In this contract, the supplier offers that he will buy back the remaining obsolete inventory at a discounted price (Egri, 2008).
Sales rebate	A rebate is different from an order quantity discount as it only applies to items sold to end-users (Wang, et al., 2009).
Option	The options contracts are originated from the product and stock exchange. With options contract, the customer can give fixed orders in advance, as well as buy rights to purchase more (call option) or return (put option) products later (Egri, 2008).
Revenue-sharing with side payment	A side payment in a consignment contract context is analogous to a membership fee (Zhang, 2008).
Pay-to-delay	The retailer reserves Q units of the supplier's capacity in period 1 for a constant fee per unit. That commits the retailer to purchase at least Q units in period 2 (Cachon, 2003).
Consigned revenue-sharing	Under this arrangement, the supplier retains ownership of the goods and sets the retail price and replenishment scheduling/quantity. For each sale, the retailer deducts a percentage and remits the balance to the supplier (Bolen, 1988). [Liang-Tu Chen]

Different contracts will provide different risks for both vendors and retailers. On the other hand, the response to the question of "how much risk averse the vendor or retailer is?" is a key aspect which shall impact the type of contract between the SC players. For example, with a buy-back the supplier shares with the retailer the risk of left over inventory so as to motivate the retailer to increase the order quantity (Boute and Lambrecht, 2007), while in an option contract, an intermediate level of risk is in place. In addition, revenue sharing is a type of contract in which both vendor and retailer shares the risks as well. Besides, in many VMI programs the vendors make the inventory decisions on behalf of the retailers and also bear the risks and costs associated with these decisions (Chen and Seshadri, 2006).

Although in many VMI contracts the risk is in the retailer's side, but there are also many samples of supply contracts in which the risk in being transferred to vendors, for example in publishing, cosmetics, computers and so on. More references on this can be accessed in the work published by Chen and Seshadri (2006). The in-depth analysis of contract types with respect to level of imposed risk to both vendors and retailers (suppliers or buyers) needs more comprehensive study.

4. Conclusion

Today, coordinating supply chains is facing new challenges. With regard to emerging of economy and marketing concepts to supply chain management such as contract theory, game theory, pricing, and advertising, on one hand, and the impact of variable parameters such as number of products, type of demand, and number of echelons, on the other hand, the required coordination will be more and more complex and challenging. VMI-type supply chains are currently gaining great momentum in various industries worldwide. A number of companies in different industries of apparel, computer/electronics, consumer goods, food processing and retailing have put VMI policy in their strategic supply chain management programs. This attention is gradually increasing in practice while on the other hand many publications have appeared in the well-known international journals focusing on this area. In this paper, the authors discussed some aspects of VMI-type supply chains. To show the significant applicability of VMI-type supply chains, many papers were reviewed and summarized. Various aspects of literature were discussed in our review including the type of demand and model used. Our review promises the following findings and implications:

1) Since the contractual clauses in the VMI contract and the benefit concerns for each member of supply chain form a kind of game problem, the game theory is going to be one of the dominant theories facilitating VMI deployment while it also helps to evaluate the VMI effectiveness. It should be pointed out that Stackelberg is the most frequently used game model by researchers.

2) The role of contracts between supply chain members is completely undeniable. Although, this issue has not been addressed extensively in the previous literature, this paper set out to review and analyze the existing VMI contract types which can be applied in party's agreement.

3) Our analysis of the selected papers showed the following facts which should provide insights into potential areas for future research:

- More than 90% of publications have addressed single product models while the available practical trends specially in retailing industry necessitate research on multi product supply chains under VMI strategy. Two samples of multi-product VMI supply chain models can be found in the studies by Pasandideh, et al. (2011) and Yu and Huang (2010).
- Most of the current studies have focused on supply chains including two echelons. In reality, researchers should have some orientations to more complex models with more than two echelons. For sure the complexity of these problems will be extremely increased.
- "One vendor-multi retailers" and "one vendor-one retailer" VMI-type supply chains are frequent configurations used in the literature. Indeed, lack of attention to "multi vendor-multi retailers" prevails.
- According to the results presented in Table 4, there is a lack of research addressing either stochastic or fuzzy parameters in the available models. In fact, some of the parameters in VMI supply chains models have the potential to be stochastic or fuzzy in upcoming researches.
- This survey showed that VMI-type supply chain can be formulated by various contract types which will increase the level of harmonization and coordination in supply chain management. A few types of contract models such as sales rebate, revenue sharing and so on are currently used in some papers. However, utilization and evaluation of the reaming contract types is required in future researches. More research in this direction can provide researchers with new insights to compare utilization of different contract types under VMI strategy.

In summary, this can be treated as a guide for supply chain managers and practitioners who wish to deploy a type of coordination contracts for their supply chain under VMI setting. We hope this paper may provide a good overview of the current state of VMI-type supply chains for both researchers and practitioners in supply chain management domain.

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