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Report

Digital Supply Chain Management

How machine learning affects supply chain performance

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Abstract

Advanced machine learning techniques are reshaping the supply chain systems of the modern business organizations. This report aims to investigate how machine learning improves supply chain challenges based on its advantages. To do this, the existing research is reviewed and a three-dimensional theoretical model including demand management, inventory management and production management is constructed in this report. The advantages and benefits of machine learning are determined from the three dimensions. Moreover, this report hints three implication insights of the existing literature, which are the limitations of independent use of machine learning strategy in the supply chains, the advantages of combining conventional and advanced machine learning methods, and the potential of labor replacement of machine learning, aiming to contribute a deeper understanding of machine learning-based supply chain management trend.

Keywords

Supply Chain Management, Artificial Intelligence, Machine Learning, Demand Management, Inventory Management, Production Management

Contents

1 Introduction

Machine learning (ML), as a continuously growing subdivision of artificial intelligence, is gaining more and more attention in modern industries. The strong capabilities of machine learning have been considered as an indispensable enhancer for business success [1]. Based on advanced algorithms and data, ML models could train computers with capable of accurate data analysis and forecasting which will benefit the organizations to achieve a deep understanding of business potential [1]. Contemporary industries are embedded with sophisticated supply chain systems. Before the advent of ML, business organizations face a series of supply chain management (SCM) challenges including demand management, inventory management, production management [2], [3], [4], [5]. Some research, however, has revealed that the lack of precise data estimation can be considered as the main reason behind the SCM questions which can be improved by advanced ML in terms of efficiency and effectiveness [2], [5], [6]. Therefore, a cross-disciplinary research combining SCM and ML is necessary which will contribute to more valuable insights for this emerging research direction. This report will focus on investigating the advantages of implementing ML in SCM.

1.1 Aim and Research Questions

This report aims to investigate the advantages of implementing ML in SCM with respecting of identified challenges within SCM, and how can ML solve these difficulties. The following research questions will help achieve this aim:

1. What are the advantages of implementing ML concerning demand management, inventory management and production management respectively?

2. What insights into ML in SCM can we gain from existing research?

2 Result

Though implementation of ML in SCM is still an emerging research field [6]. The latest academic contributions show a great enthusiasm towards applying ML algorithms in SCM [2], [3], [4], [7], [8]. The following section will present the identified advantages of the advanced ML in supply chain and the implication insights from the latest study.

2.1 Advantages of ML in SCM

The recent applied research shows great interests to explore utilizing ML in *demand management*, *inventory management*, and *production management* of supply chain [2], [7], [8], [9], [10]. The strong capabilities of ML concerning forecasting, analyzing and information processing are considered as the main drivers for improving SCM performance. Therefore, investigating the superiorities of ML in the three aspects of SCM will realize a deeper cognition of this emerging trend.

2.1.1 Demand Management

SCM has long suffered demand fluctuation even if the demand of the final customer shows a predictable pattern [2]. That is, manufacturers upstream of the supply chain could experience volatility in their demand and market, which is well-known as the "bull-whip effect" that could largely influence the supply chain performance [2], [7]. The main reason behind this phenomenon is due to distortion of the demand information embedded in the supply chains from downstream to upstream [7].

According to Feizabadi, one of the main drivers of supply-demand inconsistency and inefficiency derives from demand forecasting updating, which indicates that the observation of demand information of each member in the supply chain transmitting the distortion that will eventually lead to upstream supply chain members forecasting with a significantly inaccurate demand [7]. Compared to traditional demand forecasting methods, ML-based forecasting approaches could benefit supply chain members with better accuracy of demand forecasting [7]. Research also suggests that ML-based techniques such as Recurrent Neural Networks and Support Vector Machines show the lowest level of forecasting error compared to trend estimation and naïve forecast, which will later on provide the chances to the members of the supply chains

overcoming the present management struggles [2].

2.1.2 Inventory management

As with the "bull-whip effect" discussed above, the supply chain collaboration barrier will strongly influence the accuracy of organizational decisions [2]. Similar to demand management, inventory management also plays an important role in modern SCM. Usually, decisions for inventory planning could influence the company's overall performance [3]. Inventory backlog could lead to over-occupation of corporate resources that will eventually impact on business efficiency, while inventory shortage will reduce customer satisfaction which in the long run will influence brand image.

The emerging ML technology, however, provides new solutions for business management. Material backorder, as one common issue for inventory management, impacts both inventory system service level and effectiveness [8]. Conventional inventory management strategies focus on achieving multi-objective optimization, viz maintaining the minimized ordering and storage costs, while leveraging the service level as higher as possible [8]. By contrast, implementation of ML tactics will solve this management need based on identifying the materials at risk of backorder before the event occurring, which can present a high opportunity to improve the whole performance of the company [8].

2.1.3 Production management

As the upstream members of the supply chains, the manufacturers are facing a series of new objectives. Increasing market demand requires the producers to provide a greater level of product and process quality in an efficient way when the uncertainties still remain in the production goals [9], [10]. This forces companies to come up with more innovative means to optimize the production flows [9].

The limitation of traditional methods which are based on modelling the relations of cause-effect can be found when handling the complicated and high-dimensional modern manufacturing tasks [9]. ML approaches, however, give contemporary enterprises an opportunity to reach both goals. A combination of Cluster Analysis and Supervised Machine Learning system enables production factories to monitor the complicated and high-dimensional product-

state-based data, simultaneously, generating appropriate results with acceptable effort [9]. This innovative application, thus, builds up a foundation to increase production's quality in the long run.

2.2 Implication insights of the ML research

The above study has shown a series of positive impacts of ML in the modernized supply chains. These experiments, on the other hand, also reveal three valuable implication insights: *the limitations of independent use of ML*, *the advantages of combined methods*, and *the potential of labor replacement* which are identified in this report.

2.2.1 Limitations of independent use of ML

Though the existing research suggests that implementation of ML could provide better results overall, the advanced techniques also show the limited improvements compared to some traditional methods [2]. In Carbonneau et al.'s experiment, the significant superiorities of the three types of ML modes only exist in the simulation data, while less significant improvements in the real foundries data set [2]. Mean average error (MAE), as the critical creteria to evaluate the accuracy of demand forecasting, has been applied to estimate and compare different prediction tools [2]. According to the horizontal comparison of conventional and ML-based means, the performance of the more traditional method – Multiple Linear Regression shows its MAE with 21.396 which is only slightly larger than 20.352 of Recurrent Neural Networks and 20.485 of Least Square Support Vector Machines and is even better than 25.260 of Neural Networks [2]. This outcome points out that purely applying advanced ML techniques is not sufficient for improving SCM performance, which the researchers note that a better information sharing and collaboration among supply chains is another important factor that the practitioners should take into account for SCM forecasting accuracy [2].

2.2.2 Advantages of combined approaches

Compared to Carbonneau et al.'s research, Feizabadi's exploration further reveals that the hybrid forecasting methods which combine the traditional statistical method (ARIMAX) and the advanced ML technique (Neural Networks) have more practical value and could contribute to a considerable improvement in SCM [2], [7]. In this experimentation, the traditional ARIMAX is

more capable to speculate the peaks in demand while Neural Networks could yield more flatten forecasting with better accuracy [7]. This sheds light on the effectiveness of hybrid implementation that the traditional approaches will empower the performance of ML in practical demand prediction [7]. The study results show that the combined approaches on average contribute to 5% improvement in predicted accuracy for the capital-intensive industry which can be rated as an enormous advancement in supply chain efficiency [7].

2.2.3 Potential of labor replacement

The emerging trend of exercising ML in SCM field has shown its potential to achieve both efficiency and effectiveness [2], [3], [7], [8], [9], [10]. This is supported by the 'learning gift' of ML which allows the algorithms sustainably improving themselves based on data training [2], [7], [9], [10]. Compared to traditional ways, ML-based implementations make the organizations more capable of handling complex tasks in a dynamic response manner [7], [9]. The current research suggests that SCM is transferring to automatic, integrated, and decision-making oriented models which implies that less traditional management forces will be required subsequently [10]. Rodríguez et al. have proved that the ML-based decision-making system can automatically synthesize the production data and the managers' experience [10]. 75% to 80% of the virtual decisions have shown the difference rates less than 5% compared to human experts [10]. With the development of computer software and hardware and the research of ML algorithms, this discrepancy rate is expected to be further reduced in the near future.

3 Discussion

The significance of this research is that a three-dimensional theoretical model that includes advantages of ML in demand management, inventory management, and production management has been built. This report points out the trend of ML replacing the traditional methods which are due to the traditional approaches insufficiently supporting the demands of modern industries in several aspects. Through refined algorithms and continuous data training, ML could enable supply chain members with strong capabilities of demand forecasting, risk material identification, and complicated production management.

Furthermore, this study reveals the implication insights of the latest ML-based SCM research from various industries which contribute to a deeper understanding of the potential of ML and the possible directions of future research.

Although this report intends to provide a comprehensive view of utilizing state-of-the-art ML techniques in SCM, the existing research in the academic field shows that the cross-disciplinary study is still in a developmental stage which limits the construction of the theoretical model of this paper [6]. The nature of the sophistication of SCM hints that this area still needs more experiments to better generalize research findings.

4 Conclusion

This report suggests that the advantages of ML techniques could benefit SCM in terms of accurate demand forecasting, avoiding inventory backorder through identifying risk materials, and handling complex production processes which will help supply chain members to achieve better performance [2], [7], [8], [9], [10]. Based on these implementations, business practitioners should note that purely applying advanced ML methodologies is not sufficient to improve SCM performance while developing hybrid strategies through integrating both traditional methods and advanced ML could contribute to more feasible solutions [2], [7]. Due to the strong decision-making ability, ML enables supply chain organizations to realize higher business efficiency, simultaneously, reducing the dependence on traditional management-labor forces [10]. Based on the above exploration, a possible future research direction would be to enhance this study by integrating more dimensions of SCM from various industrial findings.

References

[1] L. Bernardi, T. Mavridis, and P. Estevez, "150 successful machine learning models: 6 lessons learned at booking. com," *Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining*, pp. 1743–1751, August 2019.

[2] R. Carbonneau, K. Laframboise, and R. Vahidov, "Application of machine learning techniques for supply chain demand forecasting," *European Journal of Operational Research*, vol. 184, no. 3, pp. 1140–1154, February 2008.

[3] D. Singh and A. Verma, "Inventory management in supply chain," *Materials Today: Proceedings*, vol. 5, no. 2, pp. 3867–3872, March 2018.

[4] H.-H. Hvolby and J. Trienekens, "Trends and challenges in production and supply chain management," *Computers in Industry*, vol. 61, no. 9, p. 807, August 2010.

[5] R. Sharma, S. S. Kamble, A. Gunasekaran, V. Kumar, and A. Kumar, "A systematic literature review on machine learning applications for sustainable agriculture supply chain performance," *Computers & Operations Research*, vol. 119, p. 104926, February 2020.

[6] D. Ni, Z. Xiao, and M. K. Lim, "A systematic review of the research trends of machine learning in supply chain management," *International Journal of Machine Learning and Cybernetics*, pp. 1–20, December 2019.

[7] J. Feizabadi, "Machine learning demand forecasting and supply chain performance," *International Journal of Logistics Research and Applications*, pp. 1–24, August 2020.

[8] R. B. de Santis, E. P. de Aguiar, and L. Goliatt, "Predicting material backorders in inventory management using machine learning," *2017 IEEE Latin American Conference on Computational Intelligence (LA-CCI)*, pp. 1–6, November 2017.

[9] T. Wuest, C. Irgens, and K.-D. Thoben, "An approach to monitoring quality in manufacturing using supervised machine learning on product state data," *Journal of Intelligent Manufacturing*, vol. 25, no. 5, pp. 1167–1180, March 2014.

[10] G. G. Rodríguez, J. M. Gonzalez-Cava, and J. A. M. Pérez, "An intelligent decision support system for production planning based on machine learning," *Journal of Intelligent Manufacturing*, pp. 1–17, November 2019.