Case Study: Packing and Distribution Logistics Optimization of Fashion Goods

Young Jae Jang(✉) and Shin Woong Sung

Industrial and Systems Engineering, KAIST, Daejeon, Korea
yjang@kaist.ac.kr

Abstract. In this short paper, we describe the development and implementation of the optimal packing and distribution of fashion products applied to a leading outdoor fashion brand in South Korea, Kolon Sport (K/S), through the academic-industry Business Analytics project with KAIST. We explain the framework of Business Analytics defined for the project and how modeling and analysis were performed under the framework. The packing and distribution decision involves how to determine a set of different box configurations and how to distribute these boxes to stores to meet store demand. The packing and distribution problem was formulated as a mixed-integer linear program, and a solution approach was developed to efficiently solve the industry-size problem in a timely manner. The modeling and analysis were performed with SAS packages. In particular, the optimization model was implemented with SAS/OR. The proposed approach was validated with simulation and on-site pilot test. The simulation showed an improvement in the packing and distribution process of around 15% in terms of meeting the demand in the stores, and it projected a 5 $\sim$ 10% improvement in revenue. After the successful pilot test, the approach was implemented in the internal IT system of K/S in July 2015. Consequently, the mass-produced items for the fall/winter season of 2015 were distributed by the system.

1 Introduction

1.1 Kolon Sport

Kolon Sport (K/S) is the signature brand of Kolon Industries, Inc., which was founded in 1957 in South Korea and operates more than 10 different fashion brands under its business unit. The total revenue of the Kolon Industries was around US $5 billion in 2014 [3]. The K/S brand was first established in 1973 and is now one of the top three outdoor fashion brands in Korea, a country with the world's second-largest market share in the global outdoor fashion industry, as of 2014, after the United States. K/S operates more than 250 stores over the country and designs, manufactures, and distributes more than 4,000 different types of products in all sales seasons. More information about the brand can be found at its website (http://us.kolonsport.com/). Note here that K/S refers to both the brand name and the department unit in Kolon Industries responsible for K/S operations. We use the term K/S interchangeably for the two definitions.

J. Xu et al. (eds.), *Proceedings of the Eleventh International Conference on Management Science and Engineering Management*, Lecture Notes on Multidisciplinary Industrial Engineering, DOI 10.1007/978-3-319-59280-0_133

1.2 Kolon-KAIST Business Analytics Project

The Kolon-KAIST Business Analytics project was first initiated in February 2014. The Big Data Analytics Team at Kolon Industries, an internal business analysis unit in the company that was established in 2013 to analyze massive amounts of data with advanced algorithms to support business operations and strategic decisions, was primarily responsible for the operation and management of the project. The team from the Korea Advanced Institute of Science and Technology (KAIST), the top science and technological university in South Korea, was responsible for guidance and for providing the technology for the project. The authors of this paper are the primary investigators of the project in the KAIST team.

The project goal was to improve the efficiency of the packing and distribution operation at K/S with Business Analytics. We defined Business Analytics as the process of delivering a specific tangible effect on the business operation by analyzing the data, developing scientific decision-making methods, and implementing methods with advanced IT solutions. Compared with conventional business analysis in which the final deliverables are forms of reports or documents of as-is analysis, the defined Business Analytics tried to provide a way to deliver specific actions and results. In contrast to the conventional business analysis or data-driven approach, which starts with collecting data and analyzing data first, we tried a problem-centric top-down approach. We first ask, “What is the problem?” and then ask, “Can this problem be solved with data and advanced algorithms and computation?” If the answer is yes to the preceding question, we try to collect data or create a system to collect the required data. Moreover, we emphasize an algorithm-based decision. To drive an action, “specific” action should be made. Therefore, optimization modeling and algorithm development are emphasized. We also include IT implementation in the definition of Business Analytics. To deliver sustainable results rather than a one-time as-is report, implementation of the analysis procedures and algorithm into the company’s existing IT system is mandatory. This definition of Business Analytics clearly outlines the job scope of the project. It includes problem identification, data analysis to find the insight, development of an optimization model and algorithm to solve the complex problem, and then implementation of the system to derive the action.

Figure 1 shows the framework of Business Analytics that we constructed for the project. The framework describes the required techniques and corresponding departments or organization necessary to support the techniques. As shown, the framework consists of three different technical layers. The bottom layer comprises data collection and data management. The fact-based and data-oriented approach is the core concept of Business Analytics. Identifying the required data and effectively managing them were the fundamentals of the project. The IT department at K/S was responsible for this layer. The next layer addresses knowledge discovery through the analysis of data. Using data mining and statistical analysis, we tried to find new insights and knowledge or validate the existing knowledge. This function was done in cooperation with the

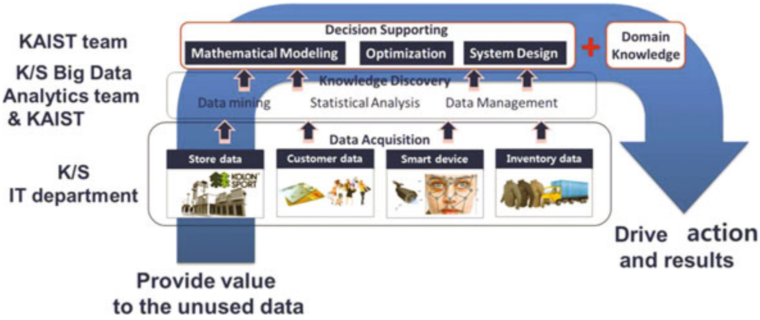

Fig. 1. Business analytics framework for the project

marketing team, business operation team, and various analytics-centric teams at K/S under the guidance of both the K/S Big Data Analytics and KAIST teams. The top layer concerns decision making. With the knowledge and insight gained from the underlying layers, this top layer attempts to support the decision for a complex problem. Mathematical optimization techniques were used in this layer. Because K/S did not have an internal team or organization using such optimization, this layer was the primary responsibility of the KAIST team.

2 Packing and Distribution Problem

To expedite the shipping process and reduce the operational costs of the distribution, K/S has been using direct delivery of their apparel products from the manufacturers, which are the third-party OEM supplier to K/S, to the K/S stores for the last several years. In the past before direct delivery was used, all of the manufactured products were shipped to the K/S warehouse, unpacked, sorted, and repacked for distribution to the stores. Given the fact that K/S distributes more than 1.6 million items in 1,000 different styles during each selling season, this repacking process required significant time and effort. Moreover, due to long delays in the repacking process, some stores did not receive products even after a sales season had already started. Direct delivery provided a significant benefit to the process. Each manufacturer packs the product with different sizes based on the size configurations given by K/S and ships their goods direct to each store. For example, K/S requests the manufacturers to provide two different types of box configuration such that for product WJ0001, Box 1 should contain 10 small, 30 medium, and 20 large sizes, and Box 2 should contain 3 small, 5 medium, and 4 large sizes. Also, K/S informs the manufacturer of which stores get how many boxes of each box configuration.

Although direct delivery significantly eliminated inefficiency in terms of delivery speed, it generated another problem. Because packing is done by third-party manufacturers, it was not realistic to make different box configurations for every store for each product, which would cause significant operational costs particularly when the numbers of products and stores are large. Therefore, the number of different box configurations was restricted to less than 10. Consequently, K/S should decide how to design the box configurations and determine which configuration and how many boxes are distributed to a store. These decisions are collectively called packing and distribution in K/S. Tables 1 and 2 show an example of packing and distribution decisions. The decisions on the configuration for each box type and the number of boxes for each type should be made in the packing and distribution process. In addition, which types and how many boxes of each type should be sent to each store must also be determined.

Table 1. An example of the packing decision

Configuration type	Configuration	Number of boxes
Type 1 Box	XS: 20, S: 25, M: 40, L: 15, XL: 10	10
Type 2 Box	XS: 10, S: 15, M: 20, L: 12, XL: 5	50
...	...	...
Type n Box	XS: 5, S: 10, M: 12, L: 8, XL: 3	30

Table 2. An example of the distribution decision

Store	1st box		...	m^{th} box	
	Configuration type	Number of boxes	...	Configuration type	Number of boxes
Store 1	Type 3 Box	1	...	Type 4 Box	1
Store 2	Type 4 Box	3	...	-	-
...	...	...	...	...	...
Store s	Type 2 Box	2	...	Type 3 Box	1

Because the OEM manufacturers charge packing fees based on the number of configuration types and the number of boxes shipped to the stores, appropriate packing and distribution can significantly reduce costs. However, due to the complexity of the configuration, decisions had been made on an ad-hoc basis that had caused inefficiency - some stores received more items than needed and some received less than needed.

3 Project Goal and Scope

The goal of the project was to develop a decision support system to optimally determine packing and distribution. The project was broken down into the following tasks:

- Demand analysis for each product style and size using the past sales data;
- Optimization modeling and algorithm development;
- Validation of the model and algorithm with simulation;
- Validation of the overall approach with pilot tests;

- Implementation of the approach in K/S's internal IT system.

The K/S Big Data team took the leading role of managing the overall project. The KAIST team took a leadership role for the first, second, and third tasks. The Sales and Operation Team at K/S was responsible for the fourth task, and the IT Department at K/S was responsible for the final task. The KAIST team also worked as the technical advisor for tasks four and five.

Note that demand forecasting or evaluation of the quantity of each product type was not within the scope of the project because of the following reason. The packing and distribution decisions were needed about one to two months before each sales season starts. However, decisions on production quantity had to be made one year before the target sales season. That is, by the time they were ready for packing and distribution, all of the products would have been ready for shipment at the manufacturers. Therefore, the product quantities for the items were given as the input parameters for the box assortment.

Although the product quantities to be distributed were known, the number of each item to be distributed to each store still needed to be evaluated. For instance, given that there are 100 medium-size winter jackets (item number WJ000111) available for the season, the number to distribute to each store must be determined. We evaluated this quantity based on the past sales data. Specifically, for each product style, we evaluated the percent of sales made by each store. This sales contribution value from the past data was used to estimate the distribution quantity for each product. For statistical analysis, we used multiple regression analysis and a standard method to estimate the future demand.

4 Packing and Distribution Optimization

The core part of the project was the development of the optimization model in the second task. As mentioned above, in this model, we determine the number and contents of the box configurations and their allocation to the stores to minimize the difference between store demand and the actual distribution quantity as depicted in Fig. 2. As indicated in the figure, the decision variables in the optimization model are the configuration of each box and the number of boxes to be distributed to each store. The demand for each store is evaluated from Task 1.

The constraints for the model are as follows. First, the types of configuration are limited. The manufacturers do not want to have more than 7 different types of configurations for each product. Second, the maximum number of boxes is restricted, as is the capacity of the box. Of course, the maximum capacity depends on the type of product. A $50 \times 50 \times 50\,\text{cm}^3$ box can hold 10 puffy winter down jackets at maximum, whereas it can hold 50 summer T-shirts. K/S has data mapping on the size of each box type and its maximum capacity for each product type. In addition, the maximum and minimum number of boxes a store receives are constrained. The last constraint is the upper limit of overstocking for each store. Note that due to the discrete nature of the problem, it may be impossible to meet the exact demand for each store. Therefore, some levels of over-shipping or under-shipping are unavoidable. However, K/S is more concerned with over-shipping. As a result, we added an over-shipping constraint, which specifies the upper limit of the allowable over-shipping to each store. The details of the general mathematical model are provided in the Appendix. The solution algorithm was also developed but is not presented in this document. For readers interested in the specifics of the algorithm, please contact the corresponding author.

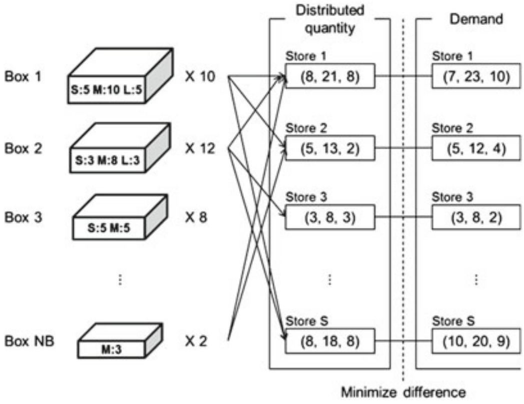

Fig. 2. Concept of the box assortment and allocation optimization problem

Similar formulations and optimization models are available in the academic literature, including [1,2]. However, the details of the models and the scales of the problem these optimization problems are trying to solve are different. To the best knowledge of the authors, this is the first work to develop an optimization model and solution algorithm at an industry-level scale and apply them to an actual business operation. Note that this paper is not intended for the academic community, and therefore the academic value of the work and scholarly implications are not discussed.

5 Validations

We conducted a simulation-based validation of the packing and distribution process in one sales season to compare the performance of the proposed method to that of the legacy procedure at K/S. The sales volume, i.e., number of sales, from the proposed method was approximately 10.16% better than that with the legacy method. We also conducted a pilot test of our approach by distributing a number of actual products for the summer season of 2015, and the result shows that compared to the legacy method of K/S, the inventory was distributed well by our method in accordance with store demand. Finally, the proposed method has now been completely implemented in the K/S's internal system for use in the upcoming packing and distribution season. The details of the validation results can be found in [5].

6 Conclusion

In this document, we describe the Business Analytics project jointly conducted by K/S and KAIST. The project has successfully developed a decision support system to assist the packing and distribution procedure at K/S. Throughout the project, the framework of the Business Analytics was first defined, and the roles and responsibilities of each team were clearly identified based on the framework. Then, multiple tasks were listed and performed by the joint team. The proposed packing and distribution approach includes a statistical data analysis that estimates the demand of stores for each product, the optimization of the box configurations and their distribution, and the IT implementation for sustainable use. The core technologies developed in the project were the optimization modeling and algorithm development. The box configuration of each box and the distribution quantity for the boxes to the stores were optimized by mixed integer programming. The proposed method was validated with simulation and actual tests in the stores. As a result, the proposed method showed significant effect, and K/S decided to implement it within their internal IT system.

The financial benefit delivered by the project is still under investigation. Based on the simulation result and on-site tests, we project that the proposed packing and distribution will improve sales by 5% 10% in terms of revenue. From the cost-saving viewpoint, we estimate that costs related to the man-hour working time for determining the configuration, the boxes, and shipping and handling will be significantly reduced. The unquantifiable contribution of this project is also very significant. The project demonstrates how advanced data-driven methods and algorithms can be incorporated into a traditional retail fashion business. It proves that in the modern data-driven society, a high-technology company is not defined by its product but rather by how it handles its operations. Mr. J.H. Jang, the Lead Manager of the Big Data Analytics Team, stated that “this project showed how the scientific method can improve the operation and provided the direction of the Big Data Analytics Team”.

Moreover, this project has been an example of successful academic-industry collaboration deriving actual tangible results. Often, academic researchers find topics for research from other academic literature or come up with hypothetical imaginary topics in the hope that these kinds of problems will be valuable to industry. However, the KAIST researchers identify multiple topics that are not known to academia but which are worthy of further investigation. The authors are also currently working on an academic paper presenting the optimization algorithm they developed for this project.

Finally, this packing and distribution problem is common across the retail fashion industry. To our best knowledge, few retail fashion companies use logical methods for the process. The process, model, and algorithm developed in this project can be further developed as a service or software solution. We discovered three patents (two applications and one awarded patent) for solution algorithms of the optimization problem similar to what we constructed [4,6,7]. Among these patents, two are from the Oracle Corporation [6,7] and one is from the SAS

Institute [4]. However, we found that there is still room for improvement in the algorithms presented in these patents.

Appendix

Box assortment optimization model

The optimization model determines the number and contents of the box configurations and their allocation to the stores to minimize overstocking and understocking. The demand for items in each store is given by a multiple regression model. Because we know the maximum demand for each item among all stores and the capacity of the box is finite, it is theoretically feasible to generate a pool of all possible box configurations by selecting numbers between zero and the maximum demand for each item and making a combination of them as a box configuration, only if the sum of the number of items in a combination satisfies the capacity. In this way, a set of possible box configuration is given.

When the box configurations and their assignments are established in K/S, several managerial and operational requirements need to be met. First, a box only contains items with an identical product type, style, and color, but different sizes. For example, for such an item with five different sizes, a box can contain two "Small"-sized items, five "Medium"-sized items, and three "Large"-sized items because the manufacturer prefers to pack items of the same product type, style, and color at one time unless the finished products are waiting until changes in production setup and raw materials are needed. Additionally, the manufacturers of the items might be different even if their product types and styles are the same but their colors are different. Second, the following are constrained: the number of different box configurations, the maximum and minimum quantities of items in a box, i.e. capacity, the maximum and minimum number of boxes a store receives, the maximum number of boxes, and the upper bound on overstocking.

Indices

S : set of stores ($s \in S$);
I : set of items ($i \in I$);
C : set of possible box configurations ($c \in C$)

Parameters

d_{is} : demand of item i in store s;
c_{bi} : integer number of item i in box configuration b;
α_{is} : understocking penalty of item i in store s;
β_{is} : overstocking penalty of item i in store s;
δ_{is} : upper bound on overstocking of item i in store s;
NB : number of different box configurations;
N_s : minimum number of boxes store s receives;
M_s : maximum number of boxes store s receives;
T : maximum number of boxes

Decision Variables

x_{bs} : number of box configuration b allocated to store s;

y_b : binary variable, which is 1 if box configuration b is used and 0 otherwise;

u_{is} : understocking of item i in store s;

o_{is} : overstocking of item i in store s

Objective

$$\sum_{s \in S} \sum_{i \in I} (\alpha_{is} u_{is} + \beta_{is} o_{is})$$

Constraints

$$\sum_{b \in B} c_{bi} x_{bs} - o_{is} + u_{is} = d_{is} \quad \forall i \in I, s \in S$$

$$\sum_{b \in B} x_{bs} \geq N_s \quad \forall s \in S$$

$$\sum_{b \in B} x_{bs} \leq M_s \quad \forall s \in S$$

$$\sum_{b \in B} y_b \leq NB$$

$$\sum_{b \in B} \sum_{s \in S} x_{bs} \leq T$$

$$\sum_{s \in S} x_{bs} \leq \sum_{s \in S} M_s y_b \quad \forall b \in B$$

$$\sum_{s \in S} x_{bs} \geq y_b \quad \forall b \in B$$

$$x_{bs} \geq 0, \text{integer} \quad \forall b \in B, s \in S$$

$$y_b \in \{0, 1\} \quad \forall b \in B.$$

References

1. Fischetti M, Monaci M, Salvagnin D (2015) Mixed-integer linear programming heuristics for the prepack optimization problem. Discrete Optim 22:195–205
2. Hoskins M, Masson R et al (2014) The PrePack optimization problem. Springer
3. Industries K (2014) Financial information http://www.kolonindustries.com/Eng/Service/service02.asp
4. Pratt RW (2014) Computer-implemented systems and methods for pack optimization. U.S. Patent Application
5. Sung SW, Jang YJ (2015) Kolon-KAIST business analytics project. Internal report, Kolon-KAIST Life Innovation Center
6. Vakhutinsky A (2012) Retail Pre-Pack optimization system. U.S. Patent Application
7. Vakhutinsky A, Subramanian S et al (2012) Retail pre-pack optimizer. U.S. Patent Application