SALES FORECASTING AND NEWSBOY MODEL TECHNIQUES INTEGRATED FOR MERCHANDISE PLANNING AND BUSINESS RISK OPTIMIZATION

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ABSTRACT

We consider a descrete newsboy problem of a supply quantity optimization to maximize profit and minimize risk objectives. Results show an advantage of introduction of time series data modelling and forecasting into simulation of demand distribution.

INTRODUCTION

Merchandising means the way in which the flow of merchandise is planned and managed from the supplier to the distribution centre (Jackson and Show 2001). Further we focus at merchandise planning defined as planning and control of merchandise inventory of the retail firm, in a manner, that balances between the expectation of target customer and the strategy of saler. Merchandise planning has a lot in common with assortment planning. Main objective of business' strategy is usually profit or revenue maximization.

Paper starts with the review of research conducted and techniques on modeling of demand and solving out supply quantity. Theory and models review implies that there is needed research on optimization techniques capable to fully integrate historical sales data analysis into profit maximization and decision risk analysis. Such approaches were focused at developing of multiple products expected profit maximisation or price management applications. We foucus at research on simulating risk of profit using econometric time series of sales. Than we solve supply quantity using risk assessment.

Sales summary data and its time series modeling has been very popular in businesses for many years (Dalrymple 1987). Its handicap is wide choice of qualitative methods differing with complexity level. Econometric, statistical, but also heuristic methods like neural networks are developed (Sastri 1992). Moreover, econometric modelling of time series is applicable for wide product and businesses range and captures sales dynamics in time. An alternative is to use logit choice model based on sales transaction data. Its developed to capture substitution of alternatives of a product.

There is proposed a technique of analysis that integrates econometric modelling and forecasting of sales into a descrete newsboy problem of a supply quantity optimization. The techniqe uses forecasted expected value of sales and residuals estimates to simulate an empirical distribution of demand needed for a newsboy problem. Owing to this technique we process aggregate multi-product data. According to theory and practice merchandise planning needs data driven techniques with formality and aggregation level adjustable by a business and feasible for decision supporting system immplementation (Hubner 2011).

In further section we discuss conditions for application of the technique. We also present results of our empirical research at the enterprise's retail merchandising. Pros and cons of the technique are discussed. Paper ends with conclusions and recommendations. We notice directions of further development of the technique in order to deepen profitability and risk analysis of product assortment and product variety decisions. The technique is extendable by a portfolio analysis of products sales and their correlations.

LITERATURE REVIEW

Merchandise planning is widely applied for retail sales and operations management. Operational research of merchandise planning consists of following aspects:

1. Customers' demand analysis and sales forecasting. Forecast of sales for entire organization, department and product wise is to be made. Product variety (width), breadth and depth as well as pricing and margin policy of a firm should be determined.
2. Determining supply quantity in order to maximise expected profit and subject to economic, financial risk and budget limit.
3. Merchandise stock control and stock keeping costs optimization.
4. Merchandise is assorted and presented usually product category wise and product competitive relations wise (Kok et al. 2009).

Regarding point 1 two main alternatives are time series modelling and microeconometric binomial or multinomial customer choice models (Kok et al. 2009). Choice is simple if business do not collect personal data of customers. Collecting such data is costly and

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unwanted by some customers. Moreover, it is very difficult to communicate with consumers for salers of fast moving consumption goods and for producers that are not being distributors. Even if data was collected there would be many problems with individual declarations: errors, incompleteness of anonymous answers or face to face communication manipulations. Earnings or spending can be claimed concerning various time scale, currency, credit or number of households members. Moreover, even such complex transactions data base does not include potential customers that resign from buying. If data is replaced or supplemented with public statistics, the specifics of a company's market position, its customers demand and its market risk are missed.

Further in the paper we consider sales time series analysis. This choice impedes individual customers segmentation. However, product portfolio dimensions and product competitive relations are not missed if sales product categories' time series or total sales that can be disaggregated. Disaggregation can be done using results of Principal Component Analysis, ABC/XYZ analysis of stocks indicators or product share-growth matrix techniques. These are only examples because the literature that studies the economics of product variety is vast (Kok et al. 2009).

Hence, aggregate sales time series analysis is chosen we resign from revenue management technique (Bitran and Caldentey 2003). Its theoretical and formal complexity is high. It is used jointly with logit choice models and sales transaction data. Revenue management techniques at least theoretically have the advantage of prices optimization. In practice many stationary retailers can implement price changes only from period to period and rather in order to make adjustments to market demand and supply determinants or to sale out seasonal products or products with close expiration date. Under such circumstances newsboy model is appropriate. Prices should be calculated from market prices. In case of different life-cycle point for market and given product comparative pricing or analogies forecasting can be used (Vinod 2005).

The standard newsboy problem is a wide known basic exemplification of the profit optimization depending on supply quantity. It is also called a newsvendor model. Demand has random distribution. There are two variants: with descrete random variable of demand and with continuous one. Supply quantity, called also order quantity, is descret or continuous appropriately as demand is. The model was extended or tested in order to:

- optimize alternative objectives of expected utility and budgeted profit (Lau 1980),
- prove optimality of the ordering rule based on the mean and the variance of demand with unknown distribution (Gallego and Moon 1993)
- capture risk influence on regular price and order quantity Agrawal and Seshadari (2000),
- minimize the cost of product variety choice (Rajaram 2001),
- introduce multi-stage supply chain dynamic programming (Kogan and Lou 2003),
- analyse benefits of risk pooling of individual demands having different level of variability (Gerchak and He 2003),
- model risk-sharing between the newsboy and the supplier (Cachon and Lariviere 2005),
- perform multi-product profit risk optimization by Vaagen and Wallace (2008),
- optimize a wholesale regular price treated as insured value in case of salvage (Watt and Vazquez 2015),
- capture advertising and marketing influence on demand and order quantity (Hrabec et al. 2017).

Gallego and Moon (1993) prove that expected value and standard deviation is all the information needed about demand distribution to figure out ordering quantity formula. Vaagen and Wallace (2008) provide an analysis of a few product variants order quantities with optimization of total expected profit, its variance and semivariance. They analyse theoretical two-state uniform distributions of variants demand with positive and negative correlations. We follow this works. However, we simulate demand distribution using empirical data about aggregate sales and results from its econometric modelling and forecasting procedure. Expected error of forecast is used instead historical mean.

The maximization of expected profit objective is the most effective decision under assumptions of stability of demand distribution and about many repetitions of the same decision which average result nearing the expected value. Lets assume that economy fluctuates dynamically or changes trend? Data modelling should result with a few following forecasts that are underestimated or overestimated. Therefore we analyse also usage of the measure of forecasting ex post error to correct the expectations and decision. Such a simulation of risk is in accordance with theory of scenario planning theory (Bishop et al. 2007).

THE TECHNIQUE OF SUPPLY OPTIMIZATION

The technique's concept is presented at Figure 1. Technique solves one of assortment planning problems and is determined by other assortment issues, business strategy and market conditions. Therefore assortment planning issues are an oval in the centre of the figure. Diamonds contain data or theory knowledge that should be help to aquire parameters of the problems. Arrows show the sequence of analysis and are signed with analysis names. One of them is theoretical and empirical analysis of preferences of business's target customer group. Aquired parameters are product width, product lines length and product assortment depth that constitute core of the business. Further analysis should concern at least these products if we want to achieve results that are viable for business and concern business risk. For currently operaiting undiversified company actual dimensions of merchandise can be taken into account.

Parameters of product prices and margins or overall trading margin are carried out from historical data about profitability. Possible adjustment for future profitability

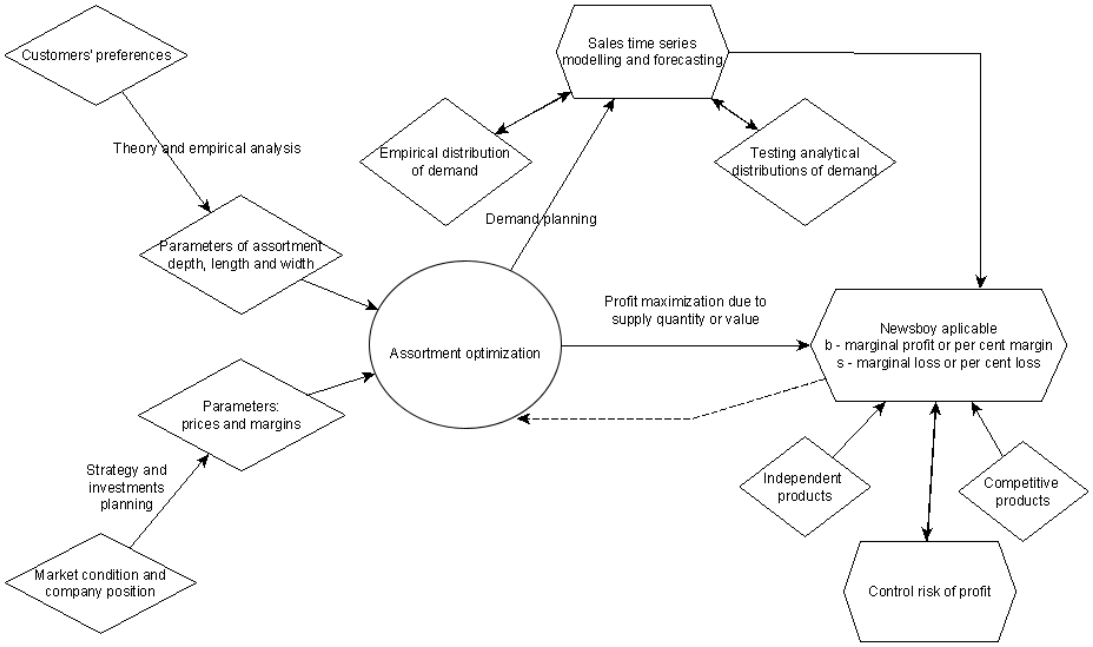

Figure 1: The Scheme of Proposed Assortment Planning Technique

can be made due to known or forecasted dynamics of market, demand, company position and strategy, and the finished investments in production or traiding capacity.

The technique concept is to integrate econometric modelling and forecasting of sales with optimization model. Hexagonal frames mark techniques.

Prior to maximize profit owing to solving supply quantity we need analytical or historical distribution of demand. Often analytical one is assumed after its validation with usage of historical data. We propose to simulate demand distribution using results of econometric modelling. In particular to use the forecast of expected value of sales. We use the standard error of the model and also expected forecast error as variability parameters of demand distribution. Validation sample of observations would allow also to calculate risk using forecasts errors and their measures.

Finally we solve newsboy problem for simulated demand distribution or distributions. Knowing margin and salvage costs parameters we apply newsboy model to one product demand and sales distribution or to multi-product aggregate sales. Appropriately we figure out optimal supply quantity of a given product or total supply value for multi-products. Total supply value and its proportional disaggregation into products' supply quantities is feasible for complements that do not compeete. Aggregated analysis holds also for substitutes if their relative prices differ slightly and price substitution is outperformed by out of stock substitution. Regarding income effects aggregate sales analysis is valid if concerns fmcg goods but not luxury gods and high value goods. In case of independent product categories their demand distributions should be analysed separately.

The dotted line shows assortment dimensions adjustment implied by the result of the technique application. Especially if additional objective is the minimization of risk of the expected profit due to competitive relations and estimated correlations. Such extension of the technique needs an appropriate risk function that takes into account product competitive relations. Modern portfolio theory is an appropriate technique.

RESEARCH

Data

We chose gastronomy and retail trade provision company located at sea ferry by a ferryman. Stocks cannot be supplied on every day basis as the analysed ferry sails regularly for a few days distance and goes back. Small orders can be done once a week. Company prefers big delivery once a month during a few days stay at main harbor. Crew members have free time.

As sales per cruise are not available in accounting reports we chose quarterly sales time series. Monthly sales analysis of supply would be the most accurate as such is delivery lead time. Additionally quarterly sales smooth weather anomalies in sales data and risk analysis is incomplete. We collected only quarter sales data and we apply the technique to this data. At least long durability merchandise can be ordered once quarterly. Other goods supply can be rescaled monthly or weekly.

Business's range consists of 3 product groups: restaurants and bars food provision, restaurants and bars alcoholic and non-alcoholic beverages, and FMCG goods provision for retailing shops. As these are generally compliments we will focus at total sales data.

Operaiting return on total sales fluctuated between 1,8 and 10%. So we assume that the highest value of 10% is the estimate of business's mark-up in relation to cost of good, service and traiding costs. Offcourse if whole supply is sold. We assume also 10 per cent of lost value of merchandise that is supplied and doesn't find demand.

It is an alternative to salvage price and discount rate. It would mean that profitability of 1,8% was achieven when 55% of merchandise supply value was sold with 10% mark-up and 45% was unsold and generated loss that accounts for 10% of oversupply:

$$\frac{0{,}1\cdot 0{,}55\cdot \text{Supply} - 0{,}1\cdot 0{,}45\cdot \text{Supply}}{0{,}55\cdot \text{Supply}}\cdot 100 = 1{,}8\ .$$

Total sales from quarter 4 of 2014 to quarter 2 of 2019 is analysed time series. Last quarter is excluded to validation sample. Equation (1) presents first order differences model that was estimated:

$$\Delta y_t = -72\,500 - 6\,312\,510 q_1 + 13\,728\,500 q_2 + \\ + 3\,061\,170 q_3 - 10\,487\,000 q_4\,, \qquad (1)$$

where q_1–q_4 are dummy variables of quarters of the year. All parameters are significant at error probability level of at most 0,01. R square equals 0,97. Forecast error is by 5% higher than standard deviation of residuals.

Forecast of expected value of total sales is calculated using the model of increment and previous quarter observation.

Further we analyse three types of empirical distributions of demand around forecast of expected sales that is 34 390 050:

(1) modelled with sales model errors, possible demanded amounts differ from historical sales time series,

(2) uniform distribution between pessimistic, neutral and optimistic scenarios of demand, where a mean of negative errors, the mean of all errors and the mean of positive errors are calculated and added to a forecast,

(3) uniform distribution between pessimistic, neutral and optimistic scenarios of demand, where from the forecast of expected value we deduct root of average square of negative errors of the model and we add root of average square of its positive errors.

Results

Calculations of total profit were made in accordance with formula (2):

$$P(z, d) = 0{,}1\min(z; d) - 0{,}1\max(0; z - d) \qquad (2)$$

where z means supply amount and d means demand amount. For different distributions of demand amounts D was calculated optimum supply z^* that gives maximum of expected profit value:

$$\pi = \max_z E[P(z, D)]. \qquad (3)$$

To analyse risk we calculate standard deviation $s(z)$. We use it to calculate maximum of low profit:

$$\pi^- = \max_z \{E[P(z, D)] - s(z)\}. \qquad (4)$$

Results are presented in Table 1. Realised profit is calculated for one observation in the validation sample using supply quantity that maximizes expected profit given in the row entitled z.

Table 1: Results for Simulated Distributions

	Distribution		
	1	2	3
z	34677366	34390050	34677366
Π	3312025	3347864	3348439
Realised profit	2951924	2980656	2951924
s	202171	128893	212697
Π^-	3109854	3218971	3135742
Arg[$\Pi^-(z)=max$]	33047325	33022934	33534602

Comparing distributions 1, 2 and 3 the last two give more actual data about risk owing to grouping negative errors into pessimistic scenario with pessimistic realisation and grouping positive errors into optimistic scenario with optimistic realisation. If errors are not grouped their values compensate themselves to 0 so if negative errors are less numerous they are on average bigger in absolute terms. Should their risk be flattened by their smaller frequency in all errors number? This is the case that occurs in the analysed data. In the analysed time series there were less negative errors but with higher average in absolute terms. Therefore standard deviation of errors is replaced with average errors in positive errors group and in negative errors group separetly for distribution 2. Root of mean squares in groups are used is distribution 3. Although demand distributions 1 and 3 differ they result with the same supply quantity decision. If errors in one or in both groups would be more variable usage of third distribution gives an advantage. Distribution 2 accounts for variability of errors levels and is also the most robust to difference in negative and positive errors frequency. Hence, we recommend usage of distribution 2 in case of empirical data without known analytical distribution. It is valid especially for small sample that can face high error of estimation. Finally the technique allowed to simulate different distributions of demand using the same time series of sales. Using distribution 2 and solving newsboy problem resulted with lower optimal supply and with higher realized profit. Using less risky objective distribution 2 resulted with the smallest supply order among distributions. The smallest supply would result with the highest profit in next quarter as sales were lower than expected.

REFERENCES

Agrawal, V. and S. Seshadari. 2000. “Impact of Uncertainty and Risk Aversion on Price and Order Quantity in the Newsvendor Problem”. *Manufacturing & Service Operations Management 2*, 410-423.

Bishop, P.; Hines, A. and T. Collins. 2007. “The Current State of Scenario Development: an Overview of Techniques”. *Foresight 9*, No. 1, 5-25.

Bitran, G. and R. Caldentey. 2003. “An Overview of Pricing Models for Reveneu Management”. *Manufacturing & Service Operations Management 5*, No. 3, 203-229.

Cachon, G.P. and M.A. Lariviere. 2005. “Supply Chain Coordination with Revenue-Sharing Contracts: Strengths and Limitations”. *Management Science 51*, No. 1, 30-44.

Dalrymple, D.J. 1987. “Sales Forecasting Practices: Results from a United States Survey”. *International Journal of Forecasting*, No. 3-4, 379-391.

Gallego, G. and I. Moon. 1993. “The Distribution Free Newsboy Problem: Review and Extensions”. *Journal of the Operational Research Society 44*, No. 8, 825-834.

Gerchak, Y. and Q-M. He. 2003. “On the Relation Between the Benefits of Risk Pooling and the Variability of Demand”. *IIE Transactions 2003*, No. 35, 1027-1031.

Hrabec, D.; Haugen, K.K. and P. Popela. 2017. “The Newsvendor Problem with Advertising: an Overview with Extensions”. *Review of Management Science 11*, 767-787.

Hubner, A. 2011 *Retail Category Management. Decision Support Systems for Assortment, Shelf Space, Inventory and Price Planning*, Springer, Heidelberg.

Jackson T. and D. Shaw. 2001. *Mastering Fashion Buying and Merchandising Management 2001*, T, Jackson and D. Shaw. Palgrave MacMillan, London.

Kogan, K. and S. Lou. 2003. “Multi-stage Newsboy Problem: A Dynamic Model”. *European Journal of Operational Research 2003*, No. 149, 448-458.

Kok, G.A.; Fisher M.L. and R. Vaidyanathan. 2009. “Assortment Planning: Review of Literature and Industry Practice”. In *Retail Supply Chain Management 2009*, N. Agrawal and S.A. Smith (Eds.), Springer Science+Business Media, 99-153.

Lau, H-S. 1980. “The Newsboy Problem under Alternative Optimization Objectives”. *Journal of Operational Research Society 31*, 525-535.

Rajaram, K. 2001. “Assortment Planning in Fashion Retailing: Methodology, Application and Analysis”. *European Journal of Operations Research 129*, No. 1, 186-208.

Sastri, T. 1992. “Multiple-Step-Ahead Prediction by Hierarchical Neural Networks“. In *Proceedings of a 1992 Joint German/US Conference Operations Research in Production Planning and Control* (Hagen, Germany, June 25-26), Springer-Verlag, 529-549.

Vaagen, H. and S.W. Wallace. 2008. “Product Variety Arising from Hedging in the Fashion Supply Chains”. *International Journal of Production Economics 114*, No. 2, 431-455.

Vinod, B. 2005. “Practice Papers: Retail Revenue Management and the New Paradigm of Merchandise Optimisation”. *Journal of Revenue and Pricing Management*, No. 3, 358-368.

Watt, R. and F.J. Vazquez. 2015. “An Analysis of Insurance in the Newsboy Problem”. www.semanticscholar/paper.

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