MODELLING OF BALTIC SUPPLY CHAIN FOR CONSUMER GOODS

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Abstract

The current economic crisis has emphasised the importance of efficient operation of the Baltic distribution network for consumer goods. To a large extent, it concerns beverages, i.e. goods characterised by the fast cargo turnover, high competition and low margins. In this article, the impact of crisis on volumes and sales prices is analysed, and the influence of quantity and location of production factories and distribution centres on costs of Fast Moving Consumer Goods is studied. Baltic Supply Chain logistics model is developed, with one producing plant and one distribution centre per Baltic country. The relevant mathematical model is based on the mixed integer linear programming method. The results of calculations based on the developed model are in line with practice of the large international company dealing with beverages in the Baltics. In the research, operational parameters for optimal Baltic Supply Chain configuration have been evaluated and possibilities for more detailed modelling considered. The findings could be useful for Supply Chain Management of other consumer goods.

Keywords: supply chain, Baltic distribution network, logistics, beverages, consumer goods.

The subject of the study is production and distribution system of Fast Moving Consumer Goods (FMCG) in the Baltics, mathematically modelled on the basis of Coca-Cola logistics system. The paper is structured as follows:

A. The Baltic market of non-alcoholic drinks and the economic crisis.
B. Logistics model of Baltic Supply Chain (BSC).
C. Mathematical model of BSC.
D. Validation of the model by practical data.
E. Future development of BSC model.
F. Conclusions.

A. The Baltic market of non-alcoholic drinks and the economic crisis

Fast Moving Consumer Goods (FMCG) are daily products with large turnover, small profit and high competition. All three Baltic countries – Estonia, Latvia and Lithuania – have many common features: similar level of economic development, comparable consumption, similar same consumption habits and established trade structure. The Baltic States FMCG manufacturing and trade chains have many common features that are the reasons, why almost all international companies perceive the Baltics as a united market now (Agafonov & Bitinas, 2010). Beverages are an example of FMCG and their BSC features are valid also for other FMCG – hence we can apply this approach to a wide range of daily products.

An assortment of beverages in the Baltics is also similar to other European countries, with minor consumption differences due to national behaviour. All drinks are divided into two large groups – with and without alcohol. The latter consists of two main categories of non-alcoholic drinks: without sugar - mineral water and aerated water, unsweetened (NACE version 2 code 1170 1130) and water with added sugar, other sweetening matter or flavoured, i.e. soft drinks, including mineral and aerated (NACE version 2 code 1170 1930). The World Customs Organization (WCO) uses similar classification in the International Harmonized System (HS) goods nomenclature (Chapter 22: Beverages, spirits and vinegar). Eurostat provides statistics of beverages consumption data in the Manufactured Goods chapter (Prodcom). Table 1 and Table 2 show the sold beverages in metric volumes and EUR for the Baltics and Poland (to benchmark with), a neighbour country with similar economic development, as well as for the total consumption of 27 European Union countries (EU27TOTALS).

The global economic crisis of 2008-2009 has given a blow to the trade of all daily products. At that time consumption of beverages in Europe on the whole had not been in a noticeable decline, and by now this FMCG market has practically overcome the economic crisis level: the sold production by quantity expressed in litres and EUR are close to the-crisis indicators. The Baltic countries, which were affected by the crisis harder, are still in the decline stage and below the 2007 year’s results (see Figure 1). The hot summer of 2009 did not help much to keep the sales volumes. It should be noted that at the time of writing this paper the operative non-statistical Baltic consumption data showed a recovery of the beverages market. The calculation of individual consumption was made according to the year 2010 population of areas.

Table 1

Market history of water consumption

	PRCCODE (NACE rev. 2)	11071130 - Mineral waters and aerated waters, unsweetened					
	Year	2004	2005	2006	2007	2008	2009
PRODQNT	Estonia	25 890	25 501	31 772	37 709	37 634	29 091
Annual sold, 1000 litres	Latvia	70 872	68 280	81 944	68 041	55 526	44 499
	Lithuania	56 080	82 605	108 627	122 591	123 584	114 596
	Poland	1 811 295	2 291 862	2 557 591	2 621 668	2 575 020	2 676 221
	EU27TOTALS	45 431 238	43 444 343	49 644 479	54 000 000	45 000 000	45 000 000
PRODVAL	Estonia	7 267	5 450	8 142	9 671	9 363	8 705
Annual sold, 1000 Eur	Latvia	9 911	9 339	11 676	13 589	12 130	10 085
	Lithuania	9 010	13 200	18 673	24 157	28 383	25 524
	Poland	210 633	309 431	382 133	404 652	440 013	327 427
	EU27TOTALS	8 936 949	9 311 717	9 702 615	9 877 082	9 391 774	9 044 083

Source: Eurostat, PRODCOM ANNUAL SOLD, NACE Rev. 2., DS-066341, viewed: 01.06.2011. Available at: *http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database*

Table 2

Market history of soft-drinks consumption

	PRCCODE (NACE rev. 2)	11071930 - Waters, with added sugar, other sweetening matter or flavoured, i.e. soft drinks (including mineral and aerated)					
	Year	2004	2005	2006	2007	2008	2009
PRODQNT	Estonia	77 925	107 974	130 610	124 003	112 473	64 334
Annual sold, 1000 litres	Latvia	30 242	35 056	36 103	42 291	36 567	24 319
	Lithuania	139 360	154 222	138 518	133 667	107 240	93 884
	Poland	2 478 250	2 419 279	2 711 321	2 806 059	2 955 666	2 864 926
	EU27TOTALS	33 077 830	32 298 107	35 000 000	34 800 000	35 296 571	34 743 790
PRODVAL	Estonia	32 200	41 223	42 759	46 100	43 324	39 558
Annual sold, 1000 Eur	Latvia	6 990	8 464	8 971	12 303	10 887	7 368
	Lithuania	25 518	32 493	37 159	42 700	34 916	31 186
	Poland	496 445	582 940	681 839	827 896	1 046 642	745 712
	EU27TOTALS	16 564 772	15 574 808	17 200 000	18 000 000	17 985 215	16 947 800

Source: Eurostat, PRODCOM ANNUAL SOLD, NACE Rev. 2., DS-066341, viewed: 01.06.2011. Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database)

Consumption of soft drinks was much greater than that of non-sugar drinks before the economic crisis, but after that the Baltic consumption of beverages became equal for both main groups. The crisis also influenced the proportion for beverages consumed in various countries. Consumption of more expensive drinks was reduced and the gap between consumption levels in the Baltics and in Poland became wider. This however forms a basis for faster consumption growth in future, which will require corresponding resources of production and distribution systems.

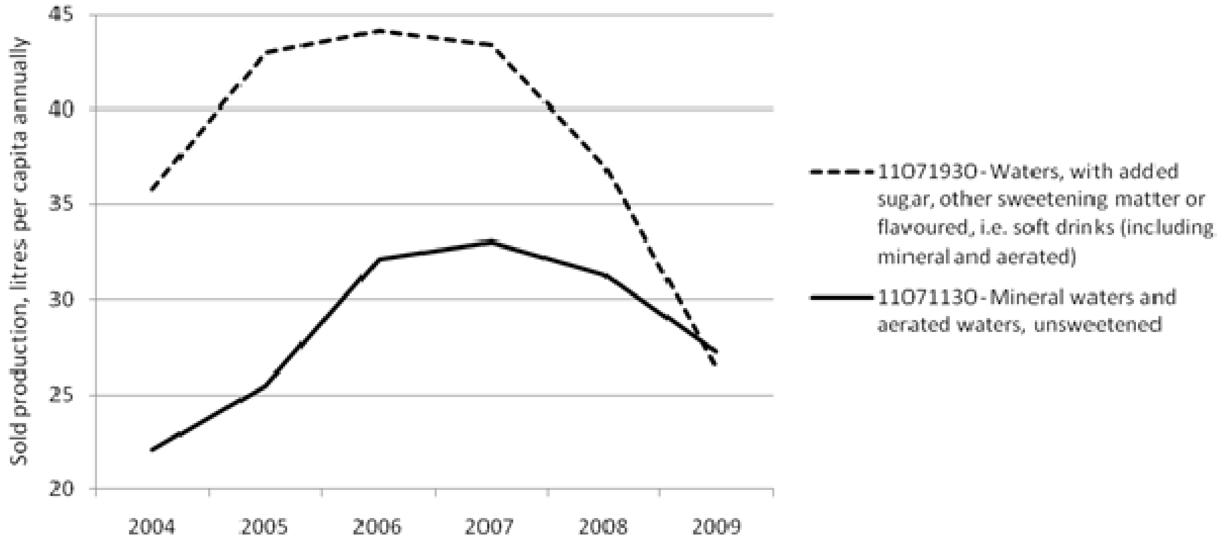

Figure 1. Consumption of beverages in the Baltics

It is interesting that the crisis has equalised the Baltic consumption of drinks with and without sugar. Supposedly, there is a minimal level of consumption for consumer goods, below which the sales would not fall.

From Figure 2 and Figure 3 we can see that trade companies responded to the crisis with the decreased volumes. In Poland and EU on the whole the prices were going down to keep the volumes. At the same time, in the Baltic countries prices for both groups of beverages were raised. Particularly it was connected with raised state taxes. Also the group's price changes were caused by changes of product mix in the beverage group.

The raised retail prices of beverages (as well as of other consumer goods) led to the inflation growth in the Baltics. It means that the crisis trade policy in the EU was directed to keeping the market size and share, whereas in the Baltics − to keeping profits. The Baltic market was able to adopt such a strategy, which means that competition in FMCG is not so strong and there are opportunities for development. In particular, the average unit price for the Baltic non-sugar beverages group became higher than that in EU27 and much higher than in Poland.

The unit price of beverages from the two groups (Figure 2 and Figure 3) is averaged over those of many various products; however, the tendency is evident due to the statistically large volume of data. It is necessary to note that the precision observed in Figure 1 – Figure 3 is connected with differences in the national statistics rules, product classifications and custom procedures.

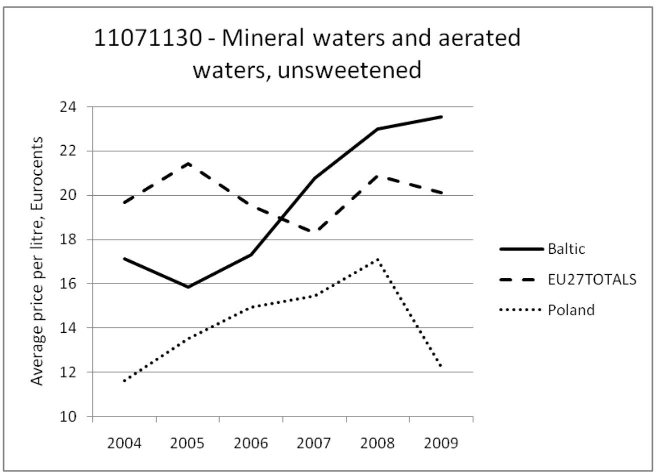

Figure 2. Price for non-sugar drinks

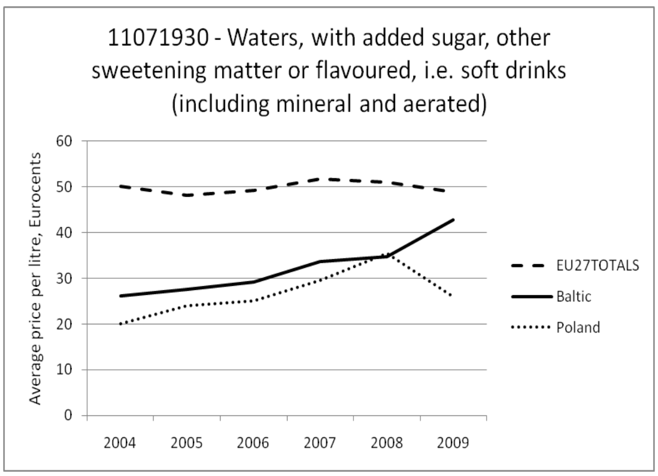

Figure 3. Price for drinks with sugar

The transportation costs usually make up a small proportion in the COGS of beverages. Therefore, the import of beverages is an attractive option, since prices (especially for non-sugar waters) are higher in the Baltic than in the EU27. Poland geographically and economically neighbouring with the Baltic countries is more ready to approach the EU27 Supply Chain parameters. Evidently, the large EU27 market is more stable than our small, the Baltics, with the population ~ 1% of that in EU27. The market of Poland, with its population 5.5 times greater than in the Baltics, also has fewer fluctuations.

B. Logistics model of Baltic Supply Chain (BSC)

The Baltic Supply Chain (BSC) for consumer goods consists of the three countries' logistics centres as a practical standard. Many traders follow such a structure (Круминьш & Витолиньш, 2007) in their Supply Chain Management (SCM). The reason is that the economic potential of all the countries: Estonia, Latvia and Lithuania − is about the same. Estonia, being the smallest in terms of territory, has a more developed economy. Lithuania has the largest territory in the Baltics, but has no higher level of economy. In addition about 2/3 of the consumer goods consumption in the Baltics are concentrated in the capitals: Tallinn, Riga and Vilnius (in a conglomerate with Kaunas). The maximum distance from these logistics centres to the farthest country destination is within one day transportation.

Foodstuffs usually are goods with large cargo turnover. Due to this, the manufacturing plants should preferably be located close to the customer concentration areas and in the vicinity of a distribution centre (DC). The BSC logistics model of three DCs and three manufacturing plants is presented in Figure 4.

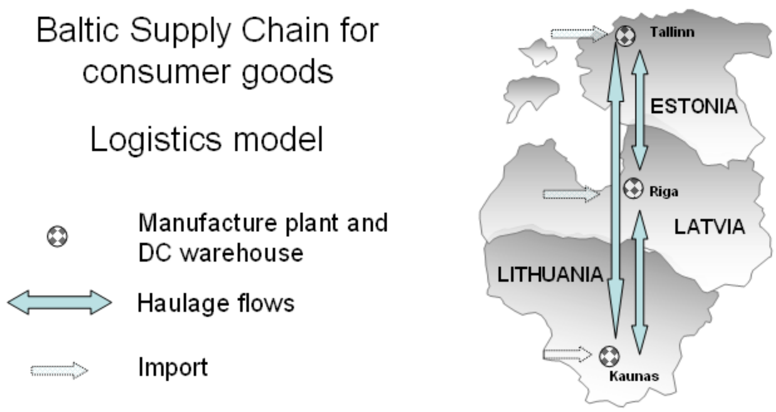

Figure 4: Logistics model of Baltic Supply Chain for consumer goods

Each DC can be supplied from three plants depending on demand as well as on production and transportation costs. Additionally, due to assortment needs and limitations on production capacities, import from the Baltics abroad is needed. The import volume is often limited by HQ due to strategic and state requirement reasons.

The plant-to-warehouse transportation of products is usually called haulage, which is performed by 20 t trailers with full trailer load (FTL) as a standard. From DC, including cross-docking operations, the products are delivered to retailers or Key Account customers by distribution trucks with a capacity of up to 10 tons.

C. Mathematical model of Baltic Supply Chain

The BSC logistics model considered above was described in mixed-integer linear programming terms (Shapiro, 2007) and used for FMCG BSC analysis. This method gives more precise results than widely used in practise the examination of a restricted number of BSC configuration. Especially it is useful in developing the Greenfield solutions.

The objective function COGSb is the minimum cost of goods sold delivered to an end-user through the Baltics. It can be calculated as

$$COGSb = COGSt + COGSr + COGSk \qquad (1)$$

We denote the country cost of goods sold as COGSt for Estonia, COGSr for Latvia and COGSk for Lithuania, where index (small letter) means location name: i = k, r or t (Kaunas, Riga or Tallinn), see definitions (2) – (4). Supply to end-users should be only from a domestic country DC, where costs are the same for various distribution network scenarios, so we are neglecting them in the calculations; transport costs are only of haulage between three logistics centres. The country cost of goods sold depends on:

- CMk, CMr and CMt – costs of product manufactured at plants in Kaunas, Riga and Tallinn are different.
- CI – costs of imported products is with practical accuracy the same for each country DC (CI is including the import delivery tariff).
- CDij – costs of delivery from "i" factory to "j" DC is a fixed transport tariff, depending on the distance only, so CDij = CDji.
- CSi – storage costs are different at Kaunas, Riga and Tallinn warehouses.

COGSk = MCk*{Qkk*CMk + Qkr*(CMr + CDrk) + Qkt*(CMt + CDtk) +QIk*CI + Qka*CSk}(2)
COGSr = MCr*{Qrk*(CMk + CDrk) + Qrr*CMr + Qrt*(CMt + CDtr) +QIr*CI + Qra*CSr} (3)
COGSt = MCr*{Qtk*(CMk + CDtk) + Qrt*(CMr + CDrt) + Qtt*CMt + QIt*CI + Qta*CSt} (4)

The variables in equations (2) – (4) are:

- Qi = (Qik + Qir + Qit + QIi) – product quantity delivered to each DC from three manufacturing plants and imported. Product quantity manufactured is equal to QMi = Qki + Qri + Qti.
- QIb = (QIk + Qir + QIt) – product quantity imported from abroad to each DC. By managerial decision QIb should be less than 30% of product produced in the Baltics: Qb = Qk + Qr + Qt.
- MCi – practical market coefficient, 0 < MCi < 1.
- Wi – workload of plants in Kaunas, Riga and Tallinn has value in interval – (0.1). In the limiting case the value should be binary (1 or 0) and match the fully operated or closed manufactures.
- QWi – warehouse capacity in Kaunas, Riga and Tallinn (taking into account the option of rented premises the value can be variable).
- Qka, Qra and Qta – average inventory level in country storages.

The fixed parameters of mathematical model are:

- Fk, Fr and Ft – forecast of demand per country.
- QSi – safety stock in Kaunas, Riga and Tallinn DCs.
- CSi – storage costs in Kaunas, Riga and Tallinn warehouses.
- Mk, Mr and Mt – manufacture capacity in Kaunas, Riga and Tallinn (QMi = Mi * Wi).
- CMi – manufacture costs at Kaunas, Riga and Tallinn plants.

The constraints for (2) – (4) are:

- QEi = (QBi + Qi – Fi) – ending inventory should be larger than or equal to the safety stock, where QBi is an opening inventory.
- The work load of plants in Kaunas, Riga and Tallinn cannot exceed the nominal capacity – no overtime is allowed.
- The country warehouse capacity has to be larger than a safety stock and less than the maximum allowed.

The developed software program has a number of reports and graphs.

D. Validation of the model by practical data

The mathematical model allows calculating the influence of cost changes on the manufacturing, haulage, storage, distribution and import at operations of a production plant and a distribution centre in each of the Baltic countries. As an example, using the developed model the BSC for Coca Cola products has been investigated.

The Baltic region is a part of the territory under the exclusive operations of one of the world's largest Coca-Cola bottlers - Coca-Cola Hellenic Bottling Company (CCHBC), which, as a multinational company, has well-developed standards of the business process. The Baltic Supply Chain in CCHBC means manufacturing, warehousing, distribution, transportation, quality assurance, planning and procurement.

CCHBC, according to the company standards, measure the turnover in unit cases equal to 5.678 litres or 24 servings (single food or drink portion) or in pallets of about 800 litres. Figure 5 shows the current structure of CCHBC BSC, which fits well into the developed model. Currently, there are: one producing plant in the vicinity of Kaunas, three DCs in each capital of Baltic States, three per country cross-docking points without storage facilities, and import (mainly from Poland now).

Hence operation mode of CCHBC is a particular case of the developed model that allows analysing and optimising the BSC. An example of calculation, based on one of the possible scenarios, made by mixed integer linear programming technology is given in Table 3.

The parameters of logistics centres volume flows and costs mean the country total. Change of variables, fixed parameters and constraints determine optimal flows from production plants and import size. Varying of parameters gives the limit values, when, for example, production in factory is not profitable. Also, the model allows easy evaluation of the influence of raising the fuel prices on changing the optimal product flows.

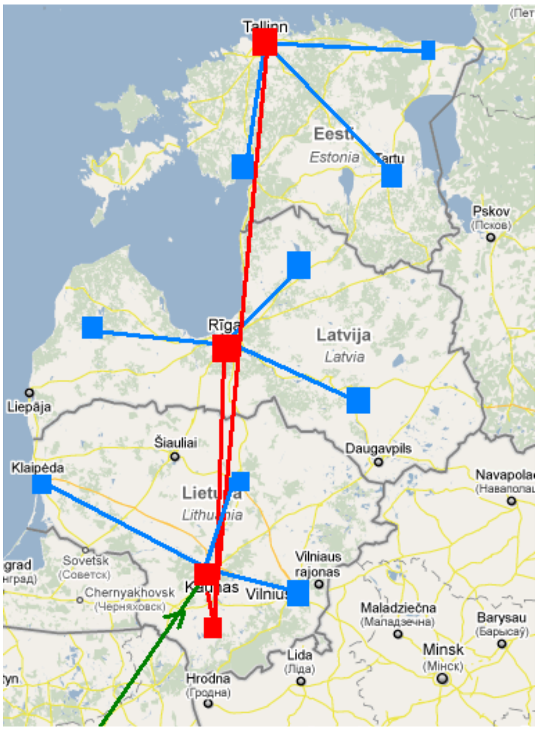

Figure 5. Baltic Supply Chain for Coca Cola products

Table 3

Calculation example

	Demand (forecast)	Cost of product manufactured	Storage costs	Delivery cost to Kaunas	Delivery cost to Riga	Delivery cost to Tallinn	Safety stock	Manufacturing capacity
Kaunas DC	**9 200**	**0.74**	**0.21**	x	**0.105**	**0.200**	**200**	**8 000**
Riga DC	**4 000**	**0.58**	**0.19**	**0.105**	x	**0.110**	**200**	**12 000**
Tallinn DC	**4 700**	**0.68**	**0.23**	**0.200**	**0.110**	x	**150**	**6 000**
Baltic	**17 900**						**550**	**26 000**
Import		**0.52**						
	Workload	Delivered from Kaunas	Delivered from Riga	Delivered from Tallinn	Imported	Delivered total	Ending inventory	BSC costs
Kaunas DC	**0%**	**0**	**3 830**	**0**	**5 370**	**9 200**	**200**	**3 251**
Riga DC	**65%**	**0**	**4 000**	**0**	**0**	**4 000**	**200**	**1 219**
Tallinn DC	**78%**	**0**	**0**	**4 700**	**0**	**4 700**	**150**	**1 662**
Baltic	**48%**	**0**	**7 830**	**4 700**	**5 370**	**17 900**	**550**	**6 132**

E. Future development of BSC model

The developed model reflects the main operational features of FMCG BSC and gives quantitative optimal parameters for SCM. The calculations have been done for a one year period. Results for longer time spans are achievable using the long-term demand forecasts. The multi-period planning methodology of the kind was developed in various works (e.g. Shapiro, 2007).

The results of calculations shown in Table 3 give an integral scope of BSC operations. More detailed BSC analyses can be obtained by synthesis of the developed model with a specific transport routing software by including costs of distribution to the end users. Such an approach can also help to optimise the distribution by taking into consideration direct deliveries from a DC or a factory of one country to the end users of another country, for example in the border areas.

An important direction for better control over the BSC is evaluation of the influence exerted by changes in the capacity and location of manufacturing plants and DCs. Nowadays, this task is a challenge for BSC of various consumer goods. Historically chosen locations of producing plants and DCs are not always corresponding to the today best terms. The calculations by discrete integer linear programming can help to choose the optimal configurations between various possibilities. For this purpose, the model has to be supplemented by financial parameters of fixed and variables costs for closing old facilities and opening new ones. All this is achievable using the technology of discrete-event simulation (Verma & Boyer, 2010).

In the paper the integer parameters of two large beverage groups consisting of many products have been analysed. The practical optimisation of BSC for a specific company needs taking into account the whole assortment of products. In the first approximation this can be done by selecting the most valuable product (ABC classification method based on the 20/80 Pareto principle) and optimising sums of objective functions for each product.

These are the tasks for future investigations.

F. Conclusions

1. The logistics and mathematical models of Baltic Supply Chain for consumer goods have been created that describes the FMCG distribution operations in three countries. The calculation model is based on mixed-integer linear programming and can give optimal parameters of SC.
2. The developed BSC model has been verified by CCHBC data and has shown the satisfactory accuracy. It is concluded that the model is capable of producing the practical recommendations for optimal FMCG distribution network.
3. Various scenarios of SC structure have been calculated by variation of fuel price, storage and manufacturing capacities. Optimal Baltic Supply Chain network configuration for one soft drink product manufacturing is evaluated with one plant located in Latvia. More precise results need more Supply Chain parameters consideration – full range of assortment and longer time span.

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