Forecasting, Production and Inventory Management of Short Life-Cycle Products: A Review of the Literature and Case Studies

The evolution of consumer behaviour (a dual demand of a large variety and personalised products) has encouraged firms to enlarge their product range. As a result, certain products have a very short life cycle (a few weeks to a few months). The supply chain for these products cannot be exactly the same as for mass-market products. In this article, we propose a literature review specific to short-life-cycle products' supply chain. We cover the three following fields: demand forecasting, inventory management, and production management. We also present the results of two studies that we have conducted: the first deals with demand forecasting for CDs and the second deals with the printing policy for an annual guide. The absence of sales history in the case of short life-cycle products does not allow the use of classical models for calculating forecasts. Specific models are then used: the Gompertz model and the logistical model. For inventory management, two policies can be considered: a single supply or two. The results of the study conducted on the policy of edition of an annual guide showed that the total cost of the second policy is lower. The production management of short life-cycle products can be based on the following triptych: modular design, delayed differentiation and flexibility.

Keywords: product life cycle, short-life-cycle products, demand forecasting, inventory management, production organisation

Introduction

Studies dealing with the evolution of consumer behaviour show that consumers, on the one hand, are looking for diversity in the consuming process (or at least a wide choice) and, on the other hand, want to use the product to set themselves apart. Certain products, therefore, have a very short life cycle (a few weeks to a few months).

Other products, by their very nature, have a life cycle that is limited by their technology or their use. To work within these expectations, firms find it necessary to manage more and more items with shorter and shorter life cycles. This tendency leads to several consequences.

Increased difficulty in coming up with reliable sales forecasts

As a result of this evolution, the forecaster is faced with two new problems:
• The reduction of product life cycle limits the depth of the
We propose, in this article, to present a literature review covering short-life-cycle products’ supply chain in terms of demand forecasting, inventory management, and production management. We will also present the results of studies that we have conducted: the first deals with the demand for CDs and the second with the printing policy for an annual guide.

The absence of sales history in the case of short life-cycle products does not allow the use of classical models for calculating forecasts.

Demand Forecasting
Problems
Demand forecasting for short-life-cycle items is not part of the classical process of time series analysis. In fact, the choice of a forecasting method (Giard, 2003) is a function of a certain number of criteria, such as the length of available history, the existence of seasonal variability, and so on.

We can list three categories of short-life-cycle products:

- Products created for a single season (textile-clothing) or for a particular occasion (a Mother’s Day present package)
- Limited-life-cycle products (CDs, DVDs, books, etc.)
- Products with very fast technical obsolescence (Decker & Gnibba-Yukawa, 2010), such as mobile telephones, computers, GPS systems, and so on

All of these articles have a common characteristic: the lack of historical references.

It is also appropriate to distinguish between (1) products with the possibility of replenishment (e.g., mobile phone, laptop, etc.) and (2) products that can be replenished quickly (e.g., CDs, DVDs, etc.) and products with a long replenishment period (e.g., textiles).

Three forecasting problems can be identified:
1. Forecasting total sales (total sales over the entire sales period)
2. Forecasting by period, usually monthly
3. Replenishment forecasting (possibly)

The results of case study on the industry of CD are presented. So we will, first introduce this industry.

Context of the industry of the CD

We develop in this section the most important characteristics of the industry of the CD.

Distribution types
Distribution is realized through networks (specialized distribution, hypermarket / supermarket, wholesalers) which behavior is different in terms of:
- Facing implementation,
- Replenishment,
- Inventory management.

These distributors represent an intermediate level between final demand and the producer.

Great number of references with very different behaviors
There is very different behavior of permanent articles (as classical music) and fashion articles (example of “Single” disk).

Items with very short life cycle
Some articles have very short life cycle, only few weeks.

A volatile market
The market of CD can change fastly. The result of this fast changes is very high stock which is reduced sometimes reduced by the destruction of the products.

Management of returns
The excess inventory in the distribution are re-shipped and refunded. This device can lead to adverse effects of order with high
quantities (gross order) followed by returns. The difference between gross orders and returns is called net orders.

*A retro-active loop amplifier: The “Hits”*

The fact that an item is among the top 10 Hit increases the orders, mainly from the wholesalers, by amplifying the demand. If the item decreases in Hit, the opposite phenomenon is observed.

*The strong influence of advertising or promotional policy on the demand*

We can mention:
- The Special Operations (SO): commercial actions planned six months ahead on a group of articles.
- Television’s Advertising campaigns: very focused on one article (sometimes single and album). They are often scheduled at the last moment to take advantage of blank advertising space.
- The event: promotion done by the artist on radio or on television.
- The advertising poster

*An implementation and replenishment*

When a new article is launched, a first order is done. It is followed by replenishment order according to demand observed in distribution.

*Large variety of articles due to packaging*

The same article (with the same gencode) may be packaged differently depending on the type of distribution.

*Statistical forecasting methods for short-life-cycle products*

The absence of history for these articles does not allow the use of classical forecasting methods based on historical analysis: analysis of seasonal variations, smoothing methods, and the model of Holt, Holt-Winters, and so on (Giard, 2003).

In this context, the forecasting method is chosen by taking into account its use and production constraints (continuous or by batch): either the company requires forecasts for each sales period (monthly or weekly) because it has relatively a rapid and inexpensive production or restocking capacity, or it is only interested in a forecast of total sales (batch production or single or quasi-single restocking).

**Forecasting demand by period**

The objective is to calculate a forecast at the level of the family in question (mobile telephones, computers, GPS systems, etc.) and to apply this forecast to each article. The useful data are therefore made up from the family sales history.

Three stages are, therefore, necessary:

- **Stage 1**: Constitution of families of homogeneous articles found in the market (same technical characteristics, same price range, etc.)

- **Stage 2**: Forecasting at the family level by a classical method of historical analysis (exponential smoothing)

- **Stage 3**: Breaking down the forecast by article as a function of the article of reference, weight of a similar article, market estimation, and so on

**Forecasting by period and estimation of total sales**

The objective for this task is to calculate a forecast by modelling the product life curve (Abbas & Hirofumi, 1996; Niu, 2006) and by historical analogy (CDs, DVDs, books, etc.). The useful data are the accumulated observed sales in the start-up phase.

We will consider two main models of the life curve: the Gompertz model and the logistical model.

*The Gompertz model*

This model is formulated as follows:

\[ y_t = e^{a + b r^t} \]  

where \( a, b, r \) are the model parameters.

We are concerned with a curve which evolves in an “S” shape, that is to say one that increases rapidly then slows down after an inflection point. That is the typical evolution of the sales of a product: the sales are zero at the beginning (\( t = 0 \)) then reach saturation (\( t \to \infty \)).

We note the following properties:

- If \( t \to \infty \) then \( y_t \to 0 \) if \( b < 0 \),
- If \( t \to \infty \) then \( y_t \to e^r \) (\( e \) is the base of natural logarithms).

The parameter \( r \) takes into account the speed of the process: the lower the value of \( r \), the more rapidly saturation is arrived at. The parameter \( a \) characterises the saturation threshold (threshold = \( e^r \)). Finally, the parameter \( b \) is associated with the origin.

The inflection point of the curve is fixed (the second derivative vanishes \( \frac{d^2 y_t}{dt^2} = 0 \)); it is arrived at when cumulative sales represent 36.8% of the saturation threshold \( e^r \).

Modelling of the sales during the first 10 weeks of distribution of a CD by a successful artist leads, for example, to the following result: \( y_t = e^{366,813 - 12.81 t} \). The saturation threshold is, therefore, equal to \( e^{366,813} = 366,813 \) units. The total sales of this CD will, therefore, be about 367,000 units. Figure 1 illustrates these results.

*The logistical model*

The logistical model can be expressed in the following way:

\[ y_t = \frac{y_{\text{max}}}{1 + b r^t} \]

where \( y_{\text{max}} \) is the saturation threshold, \( b \) and \( r \) are two parameters of the model (-1 < \( r \) < 0).

The properties are as follows:

- If \( t \to \infty \) then \( y_t \to 0 \),
- If \( t \to 0 \) then \( y_t \to y_{\text{max}} \)

The inflection point of the curve is fixed; it is reached when the cumulative sales reach 50% of the saturation threshold \( y_{\text{max}} \).

Using the same data as previously, the estimated logistical model is

\[ y_t = 349,902.54 \times \frac{1 + 18.44 t}{1 + 18.44 t + 0.78 t^2} \]

The saturation threshold, according to this model, is equal to about 350,000 units sold.

The parameters estimation of these models makes use of nonlinear
estimation methods (Greene, 2005). These methods have limitations because they assume an evolution of sales that follows a particular form (even though the parameters allow a very large variation of profile), which sometimes is perturbed by unusual events (special offers, shortages, etc.).

For further discussion on the comparative performance of the two models see (Morisson J., 1996).

**Forecasting demand over the entire period**

The process draws on the product life curve. It is based on the accumulation of orders recorded and the status of the promotional tour as explanatory factors (Baglin and al., 2007; Bourbonnais & Usunier, 2007).

The objective is to calculate a sales forecast (the most often cited is in the textile-clothing sector) by integrating the progressive accumulation or orders during the promotion (the orders start to be placed six months before delivery). Let us take the following intuitive example: if by week six the accumulation of orders for a summer short-sleeved shirt is 30,000 units and that, for the previous year, for the family of summer short-sleeved shirts, the orders at week six were for 420,000 shirts, with total sales for the season of 920,000, we can conclude that the total sales for the current season for the summer shirt will amount to 30,000 x 920,000/420,000 = 65,714 units.

The forecasting methodology, although a bit more complex, is based on this analogical principle.

We specify a relation for an instantaneous cut (that is to say, a model where all of the data used are expressed for the same date), integrating two explanatory factors:

- The fraction of the potential sales following a visit by a representative (as shown in the turnover ratio of all of the clients visited to the total turnover of the company or, perhaps, the family of articles)
- The accumulation of orders (weekly series representing the accumulation of orders as of the launching of the collection)

The general model can be written in the following way:

\[ VT = a_0 \times PPV^{a_1} \times PC^{a_2} \]

or else

\[ \log VT = \log a_0 + a_1 \log PPV + a_2 \log PC \]

with

\[ VT = \text{total sales for the season, for a family of articles,} \]

\[ PPV = \text{fraction of the potential sales following visits, for this family}, \]

\[ PC = \text{accumulation of the orders, for this family}. \]

The sample is an instantaneous cut. For each week during which the collection is sold, it corresponds to the history of orders for articles from the same family.

The parameters \( a_1, a_2 \) are the weighting coefficients of each explanatory factor, which are represented in terms of elasticity:

- \( a_1 \) elasticity of total sales to clients visited,
- \( a_2 \) elasticity of total sales to orders recorded.

The parameter \( a_0 \) (constant term) tends towards 1 at the end of the season.
Use of weekly models

There is not a single model, but many different models as the number of weeks in the promotion (about 20 per season in the textile-clothing domain). In fact, it is appropriate to integrate more and more accurate information according to the state of advancement of the promotion. The model for week \( i \) can be written as

\[
\log VT_i = \log a_{0,i} + a_{1,i} \log PPV_i + a_{2,i} \log PC_i
\]

with

- \( VT_i \): total sales for the season, estimated at week \( i \),
- \( PPV_i \): the fraction of potential sales following visits at week \( i \),
- \( PC_i \): orders accumulated in week \( i \).

The parameters \( a_{0,i}, a_{1,i}, \) and \( a_{2,i} \) are the regression coefficients estimated from the sales observed week by week for a family of articles of the preceding year.

The coefficient \( a_{1,i} \) decreases, tending towards 0 as the promotion advances, whereas the coefficient \( a_{2,i} \) increases and tends towards 1 at the end of the promotion (the representatives have contacted all of their potential customers).

Forecasting use

Thus, each week, based on the information transmitted by the representatives (most often by means of portable computers), it is possible to estimate more and more accurately the total sales for the season for each article. All that needs to be done is to reinsert the two data sets (orders and, therefore, the new total and the fraction of potential sales visited) for the year and the current week in the model, estimated on the basis of the preceding season.

The forecast can be made at the level of the item or at the level of the item colour, but rarely at the size level for reasons of volume (standard breakdown tables by size are then used).

Procedure for estimating the coefficients

Generally, the coefficients are estimated at the level of the family of products, which implies the application of the same forecasting model for all of the articles belonging to a single family.

The estimation of the coefficients is done using a technique of multiple regression applied, successively, for the 20 weeks that make up the season, which provides the set of 20 x 3 coefficients for the model (20 weeks x \( a_{0,i}, a_{1,i}, a_{2,i} \):

\[
\log VT = \log a_{0,i} + a_{1,i} \log PPV_i + a_{2,i} \log PC_i \text{ for } i = 1,20.
\]

It is useful to make up 20 samples composed of \( n \) articles selected in a family (\( n > 30 \)):

- the series for explaining (VT) the total sales of the article \( j \) for the season, \( j = 1, n \),
- the first explanatory series (PPV), the fraction of potential sales visited in week \( i \),
- the second explanatory series (PC), the accumulated orders by week \( i \) for the article \( j \).

Thus, 20 regression results provide an estimate of the 20 coefficients that are applied to the following season.

In order to be effective this forecasting method requires a good deal of care. The model coefficients are specific to each week. It is, therefore, necessary to establish perfectly the correspondence between the various regression coefficients (for a given week, calculated on the basis of the preceding year) and the real state of advancement of the promotion (to use the data for the same week in the current year, to fill out the model). A shift can lead to biased results.

Planning restocking

The closer we are to the final demand, the shorter the time remaining for dealing with the orders. The company must, therefore, be ready to react quickly to a change in the final demand (Bourbonnais & Usunier, 2007).

How does one obtain information on the final demand? We are particularly interested in two specific tools of SCM (supply chain management): CPFR (collaborative planning forecasting and replenishment) and SSM (shared supply management).

CPFR (Collaborative Planning Forecasting and Replenishment)

CPFR is a collaborative process among producers, suppliers, and the distribution network to ensure overall management of the logistic chain. It is based on the communication standards of the computerised data exchange. The process aims to integrate commercial strategies of partner companies. The transmission of payments and promotion planning makes it possible to develop demand forecasts.

The advantages of CPFR are numerous:

- Synchronisation of actions and therefore flows
- Close estimation of the final demand
- Producing a unique forecast for all participants
- Anticipation of anomalies
- Problems solved a priori rather than a posteriori
- Reduction of inventories all along the logistical chain

The limitations of CPFR may be due to possible failures of a partner:

- Absence of the will to collaborate
- Inadequate competence
- Technical limitations

SCM (Supply Chain Management)

The objective of the SCM is to optimise the efficiency of the supply chain. It is a method within the framework of ECR (efficient consumer response) techniques and includes a strategy of continuous resupply.

By making use of a collaborative approach, the supplier becomes co-responsible for supplying clients based on received information. The management of supply to the distributor is transferred to the manufacturer via a shared process. The supplier is no longer restricted to simply executing the orders sent by the clients but, based on information concerning stocks, sales, promotion planning, and so on transmitted by the distributor, the manufacturer can prepare forecasts of needs and thus
adapt production and logistical resources.

Based on sharing of information, on cooperation, and the adoption of a win-win strategy, the SCM realises its objective of reducing inventories and stock outages (improving service), passing from a logic of pushed flows to a logic of pulled flows and the adaptation of means and resources to the real needs of the consumers.

The partners, the manufacturer, and the distributor decide to
• Share the management of procurement
• Establish a logistical dialogue based on negotiated performance objectives

Table 1 summarises the various forecasting models as a function of the objective sought.

### Supply of Short-Life-Cycle Products

The term supply is used here both for the supply as well as for initiating production.

The context

The supply of this type of product is characterised by three structural components:

- A localised demand limited by a horizon of a few months at the most, without exploitable history. This often leads to forecasting based on analogy. The impact of the present time is strong (chance events, unanticipated competing campaigns, etc.) with no hope of later compensation, accentuated by feedback information often slow in arriving and badly adapted to the life cycle. This leads to a considerable risk of forecasting error.
- Possibilities of correction are very limited: the number of possible resupplies is very low, often limited to one or two.
- A strong penalty in case of a poor adjustment of inventories: stock outages lead to lost demand or expensive urgent corrections and unsold items have almost no residual value.

What characterises the difficulty in managing this type of article is not so much the absolute lifetime of the article but the number of resupplies that can technically or economically be made during the life of the article, this number necessarily being close to one. In this sense, paradoxically, the definition of a fiscal policy of annual collection of taxes goes with the management of a short-life-cycle product.

The problem

The three fundamental questions are as follows:
- How many resupplies are planned for during the life of the article?
- What is the quantity for each resupply?
- What criterion should be chosen to evaluate the effectiveness of the supply policy?

In Table 2 we try to classify the short-life-cycle articles as a function of the type of supply policy and the nature of the demand. The demand can be expressed only once over a very short time period within the management horizon (the typical case for Christmas trees) or can be repeated for similar references, as is the case for the demand for a daily or weekly newspaper.

The technical and industrial constraints on the location of the supply source can imply that a single supply would be realisable or else one main supply followed by occasional restocking, as would be the case for certain seasonal fashion articles.

When the context is uncertain, the policy evaluation criterion deserves some thought in order to make an appropriate choice.
absence of probability to influence the various levels of demand, it is not possible to evaluate the probability of the consequences of a management rule. The notion of classically used mathematical expectation is not applicable. It is possible, in this case, to make use of criteria such as worst imaginable case evaluation or to measure the spread between the result of the decision taken and that which would have been obtained if, by chance, the best decision had been taken. One would then adopt the decision that reduces the worst case effect. These criteria have the disadvantage of directing the decision maker towards refusal of risk taking and, therefore, to lose the opportunity for possibly associated gains.

Faced with this observation, it is, explicitly or not, the concept of mathematical expectation that guides the choice of action even though the probabilities of the level of demand have been estimated a priori.

The concept of mathematical expectation is based on the classical notion of the mean. There is, therefore, an implicit notion of compensation, the possible losses being compensated for by the gains. This notion of compensation is entirely pertinent in the case of cyclic management of multiple supplies or of the simultaneous or repetitive management of a line of reference because it then corresponds approximately to the real gain obtained. In the case of a single supply of a single item, this mean does not correspond to anything real; it must simply be considered as an abstract quantitative indicator making it possible to establish a hierarchy among the various policies.

If the use of mathematical expectation is the best choice as the lesser evil, it still remains to define what should be measured: the profit margin? the unsold stock? demand satisfaction?

The sales manager will choose the profit margin, the logistics director will choose to minimise the unsold stock that must be returned, and the marketing director will opt for demand satisfaction.

A classical situation

An article is procured at cost (cost of production or delivered purchase price) \( pr \). This article is resold at selling price \( pv \). Let us define the gross profit margin by \( M = pv - pr \). If unsold, the article is put on sale or recycled at a price \( ps < pr \); the cost of the unsold item is, therefore, \( I = pr-ps \).

What is the optimum size of the supply lot based on the mathematical expectation of gain? The law of demand is assumed known and defined by its distribution function \( F(L) \) corresponding to the probability that the demand (not the sales) of the article is strictly less than the level \( L \).

Let us consider the situation marginally: the supply lot must be at least of size \( L \) if the economic balance of the supply of the \( L \)th article is positive.

The mathematical expectation of this balance is

- For financial receipts: \( p(1-F(L)) + ps F(L) \) where \( 1-F(L) \) represents the probability that the demand will be greater than or equal to \( L \).
- For payments: \( pr \)

The optimal lot \( L^* \) is characterised by the balance between receipts and payments, that is, \( p(1-F(L)) + ps F(L)=pr \), which, translated by Silver and Peterson (1985), becomes

\[
F(L^*) = \frac{pr-pr}{pr-pr+ps-pr} = \frac{M}{M+I} \quad (1),
\]

where \( R= M/I \) is the ratio of the profit margin to the cost of the unsold item. The size of the supply lot depends uniquely on this ratio. If this ratio is large, \( L^* \) approaches the maximum estimated demand; if it is small, the lot will be equal to the minimum demand. For example, if this ratio is 4, the supply should cover the demand with a probability of 80% with, therefore, a risk of outage of 20%. Let’s make it clear that covering the demand with a probability of 80% does not mean that only 80% of the demand is satisfied; generally, much more is offered.

For example, for a ratio \( R = 4 \) for a product whose average expected demand is 200 articles for the life cycle, with a standard deviation of 100, covering the demand (assumed to follow a usual law) with a probability of 80% comes down to supplying \( 200 + 0.84 \times 100 = 284 \) articles. In this way, 95% of the expressed demand will be satisfied (Silver & Peterson, 1985; Vallin, 2006). The quantity 284 is the sum of the average expected demand

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**Table 2**

| Product typology according to the demand and the frequency of resupply |
|-----------------------------|-----------------------------|
| Single demand | Repetitive for several references |
| A single resupply | Gastronomic guide, current affairs book, crop choice, Christmas tree | Newspapers |
| Several resupplies | Fashion: festive products, rapid technical evolution, fresh products | * |

*Note: We consider that management depending on several resupplies for a sequence of references comes down to classical management.*
(200) and a safety stock (84) corresponding to a particular standard deviation, here 0.84. This value is obtained by reading a table of statistics at the chosen probability of not running out of stock. In fact, one should not confuse risk of an outage with percentage of demand satisfied; it is possible to be out of stock while having ensured an excellent quality of service in the sense of overall satisfaction of demand.

Note that knowledge of the totality of the distribution is not indispensable for solving equation (1); it is enough to estimate the demand level for which the risk of an overrun is 1/(R+1). For example, if \( R = 4 \), it is necessary to estimate the thresholds for which the demand has a 20% chance of not being satisfied; more specifically, it is the size of the lot for which 20% of the shops of the same kind will lack sales.

Optimising the profit margin under the constraint of service quality

It is possible to simultaneously take into account the optimisation of the economic calculation and the quality of service. The lot, \( L^* \), resulting from the economic calculation, is obtained according to the procedure presented in the preceding paragraph. The lot, \( L_s \), ensuring satisfaction of the demand with a certain intended probability, is obtained by the classical methods of inventory management (Giard, 2003; Tersine, 1994). The manager will choose the maximum of these two lots. If this is the economic lot \( L^* \) that dominates the search for the maximum profit margin and implies a quality of service better than intended, why deprive oneself?

Otherwise, it is the requirement of service quality, which can reduce the value of the economic optimum by the danger of increasing the cost of unsold items; the potential cost of the intended service can then be measured.

In the absence of probability, a scenario approach

In decision theory with an uncertain future, one approaches the decision process by an "opposed" to nature game (Guerrien, 1995). Here, the decider has a choice of the lot size; "nature" controls the level of demand. We assume that the range over which the demand will be expressed is measurable, though it may be necessary to increase the range of fluctuation. Knowing the cost of stocking, of supply, of lost sales, and of waste, it is possible to calculate the economic balance for each hypothetical lot size and each demand scenario. In this demand-lot pivot table, called a performance table, one can choose the “good lot”:

- The one that minimises the risk of loss, whatever the level of demand: choosing the lot size that optimises the consequences of the worst-case situation, which is the prudent attitude
- The one that reduces the loss of profit, calculated for each demand possibility, by the profit difference between the best solution and the one chosen

This rather heavy approach requires the preparation of a performance table and is only justified for the most important references (reference “A” in Pareto’s analysis).

Favouring restocking

Even in the case of short commercial or technical life, it is often possible to plan restocking. A priori, this restocking can take place at any date within the forecasting horizon; it is chosen by taking into account the distribution of the demand over this horizon while keeping in mind production constraints.
This policy has the disadvantage of requiring a supplementary resupply, which is, however, generally less costly and provides the following important advantages:

- There will be a lower level of inventory.
- If there is at least a minimum of flexibility in launching the second supply, the safety stock will be dimensioned to cover only the demand of the second period, which corresponds to a lower demand.

We compare in the following two policies for printing an annual guide, re-edited each year. The demand is shown for the entire year but is essentially concentrated during the first months of the product life cycle. Two scenarios are studied:

- A single printing intended to cover the annual demand, which has the advantage of reducing the fixed launching costs but the disadvantage of having to provide for the risk of running out of stock for the entire demand.
- Printing twice, a first run of 150,000 guides covering the first four months of consumption and a second run of 50,000 guides covering the last eight months of the product life cycle.

The standard deviation of the total demand, measured over the history, is 11.5% of the estimated demand, or 23,000 guides.

We assume a certain flexibility with respect to the start of the second campaign (which does not mean that the lead time will be zero), which allows us to neglect the safety stock made by the editor for the first campaign, which will be, therefore, a run of 150,000 guides (average estimated value).

We show in Table 3 the results of the two scenarios in economic terms and in quality of service, seen from the editor’s point of view.

Not only is the cost of the campaign considerably lower for the policy of restocking (€50,800 against €60,800) but the quality of service is also greater because one expects a risk of being out of stock by 1,000 units in the case of restocking against 5,300 with the policy of not reprinting.

It may seem paradoxical that the danger of an outage is lower with the policy that plans a lower total run (102,800 units with two printings against 210,200 units). This can be explained in the case of two printing runs (a second printing is expected), whereas covering the risk is calculated from the beginning of the period with no possibility of catching up in the case of the single campaign. The same phenomenon appears in the case of a demand that is less than foreseen.

### Management of Production

Mass production is known to be optimal in terms of production costs but is not possible in the case of short-life-cycle products. Because of the great variety and strong risk of obsolescence of these products, it is not possible to produce large volumes and to make up stocks by anticipation. The risk of unsold items is important in this case and leads to a high management cost. As a result, other ways of organising the production must be considered. This new organisation must respond to

### Table 3

Comparison of policies of edition of an annual guide

<table>
<thead>
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<th>double</th>
<th>single</th>
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</thead>
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<tr>
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<tr>
<td>Outage</td>
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<td>6.40</td>
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<tr>
<td>Total</td>
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</tr>
</tbody>
</table>

This table compares the economic characteristics and the quality of service of a single launch versus a double launch. For the same overall volume of 200,000 units, the double launch policy (150,000 and 50,000) although more expensive in terms of fixed launching costs is more economical in terms of complete delivery because the variation of demand is much better controlled. One gains, therefore, on the useful stock, the safety stock and cost of outage and possible pulping (destruction).
the imperatives and special characteristics of short-life-cycle products. The most pertinent are flexibility and reactivity. However, the great industrial decisions remain the same as for the case of mass production. It is the responses that are different.

These industrial decisions respond to the following questions:
1. Product design: What products should the company offer?
2. Process design: How should they be manufactured?
3. Production capacity: How many should be manufactured?

We propose, for each of the three strategic decisions, a solution for short-life-cycle products. We shall see that it is essentially necessary to favour three axes: modular design, delayed differentiation, and flexibility.

Modular design

Mass production products are designed once and for all and it is not necessary to regularly review their design. Short-life-cycle products, however, change constantly. For example, every Christmas new models of toys are offered. But should one then always invest in highly costly designs with the danger of a high selling price? Obviously, this strategy cannot be envisioned. It is necessary to find a way to reduce these major design costs and lead times.

Modular design is recommended for these short-life-cycle products. Modular products are manufactured by assembling standard components. The objective of this type of design is to have standard reusable components for several products. One can thus reduce the number of components and increase the volume of products per component. This makes it possible to reduce the risk of obsolescence and thus reduce inventory costs. Take, as an example, the Lego line of toys. The components are standardised as much as possible in order to make them interchangeable and compatible with various models of finished products. Thus, in the course of the production process, there are fewer components for a large number of finished products. This makes it possible to reduce inventories and the associated costs. The design phase of new products is thus focused on the optimisation of the assembly of existing components. But it is not always possible to use only existing components to create new products. In this case, two possibilities can be presented:
1. One can foresee new accessories in the final assembly phase to personalise the product.
2. One can create new components as supplements to the existing components.

The uncertainty of sales is thus focused on the accessories. Let us consider once more the case of toys. The body of a doll is reused in various finished products, which are then personalised by clothing (dress, trousers, shorts, etc.) and by accessories (hat, handbag, necklace, etc.). The finished products have a short lifetime but certain components or sub-assemblies have a long lifetime and may even be standard components. The standardisation of components and sub-assemblies is advisable in the framework of short-life-cycle products or for a large variety of finished products. The more the components are standardised the more they will be compatible with a large number of finished products. Thus, for an average or low number of finished products, we have a large volume of a limited number of sub-assemblies. Standardisation of components makes it possible to capitalise on the advantages of mass production.

Mass production, for example, made it possible for the Ford Model T (Forza & Salvador, 2007) to sell for $360 in 1916 when the average going price for an automobile was $2,000. Several companies then adopted the concept by standardising not only their products but also their design, their manufacture, and their distribution.

One should favour as much as possible the existence of components when designing new products. There is a threefold interest in this approach:
1. To reduce design and manufacturing lead times: when using existent components, there is no need to look for new suppliers. The existing circuits can then be used.
2. To reduce component stocks
3. To reduce the uncertainty associated with forecasting the demand for a short-life-cycle product. One can then make forecasts at the level of components (which are standardised, if possible, and become part of several finished products).

Process design

We have seen in the previous section that modular design makes it possible to reduce inventories and sub-assemblies as well as the lead time in getting to the market. Nevertheless, a strong uncertainty remains with respect to the quantity to produce. If the choice is based uniquely on demand forecasts, one can find oneself in one of the following situations: lots of unsold items if the demand is overestimated or outages if the demand is underestimated. How can we configure the manufacturing process in order to reduce this uncertainty?

Delayed differentiation is considered in the general case of strong variation and in the particular case of short-life-cycle products. Figure 3 shows this concept. It consists of placing the differentiation of products as far downstream in the industrial process as possible. This practice tends to favour overall productivity while minimising forecasting risks. The moment at which the products are differentiated is called the order point position or the external synchronisation point (Wang and al., 2010). It is the point that distinguishes the phase of manufacturing by anticipation (constitution of the stock of undifferentiated products) from the phase of manufacturing for an order received, when the components and accessories are added to the product.
Production planning for the first phase of manufacturing is carried out based on demand forecasts. These forecasts are made for the undifferentiated products, which are fewer in number than the finished products. In this way, the forecasting uncertainty is reduced. The planning of the second phase is carried out based on firm orders. The market lead time represents the waiting time that the client must expect for delivery.

Research on delayed differentiation has evolved since Alderson (Garcia-Dastugue & Lambert, 2008) in two directions: the first deals with delayed differentiation at the level of manufacture and the second with geographical and logistical delayed differentiation.

The objective of delayed differentiation is to move the differentiation point as close to the market as possible. In certain cases, some activities have been moved from the factory to the warehouse. The ready-to-wear company Zara manufactures its products without labels and sends them to the distribution centre, which finalises the product by adding labels. Thus, each warehouse becomes a production site. This task can be performed by the logistical service providers.

Production capacity

Several research projects have dealt with the planning of production capacity in an uncertain environment. We will not consider the solution to this problem in this article. For more detailed information on the subject, see Kazemi Zanjani and al. (2010) and Lucas and al. (1999). We will rather consider the strategic decisions to be taken upstream to solve the problem of capacity in the case of short-life-cycle products.

Modular design and delayed differentiation, see (Gupta & Benjaafar, 2004), make it possible to reduce product manufacturing costs by taking advantage of mass production. Production planning is thus done at the level of sub-assemblies, which are fewer in number than the finished products and have a relatively important volume. This planning is refined by making use of market information dealing with the volume of finished products to produce in a time lapse acceptable to the client. Certain studies show that the reliability of forecasts increases when use is made of sales history over the two first weeks (Marshall & Ananth, 1999). In fact, one can, in this case, reduce the forecasting error from 50% to 10%. This recent information on the sales volume is not enough, by itself, to adapt to the demand. The production tool has to be flexible in order to exploit this fresh information and respond to the demand with a short lead time.

Flexibility can be defined (Krajewski and al., 2004) by the capacity of an organisation to rapidly and efficiently adapt to the needs of a client. There are two types of flexibility: product or service personalisation and volume flexibility.

- Personalisation is based on the ability to satisfy the unique needs of each client by participating in the design of products and services.
- Volume flexibility is the capacity to accelerate or slow down the production flow reactively in order to adapt to strong fluctuations in demand.

Flexibility can also be defined (Everaere, 1997) as a “capacity to adapt under the double constraint or uncertainty and urgency.”

Reviewing the literature, we have found several definitions of flexibility. We will, above all, consider various means of attaining this flexibility. These means can be classified in three categories: the production tool, the staff, and the organisation.

The production tool must be reactive and adapt to an increase or a decrease in production. For that, it is necessary that the maintenance be well planned and regular in order to avoid as much as possible random shutdowns. Reliability of the tool is also necessary, which makes possible the manufacture of high-quality products with a minimum of waste. The staff should be highly competent, making it possible to manage and adapt rapidly to complex situations. First-level maintenance, for example, can be performed by the operators directly to avoid long machine shutdowns. For that, it is necessary that the operators be qualified and regularly trained. Among these tasks are simple adjustments without disassembling or opening the equipment; replacing accessible consumable elements, such as display lamps, oil, filters; and so on. It is also necessary to give the staff greater autonomy (if they are qualified and well trained). They will then be in a position to take decisions rapidly.
The organisation should be decentralised to shorten the decision-making circuits and to adapt reactively to demand. It is also necessary that it be a source of development for the staff by providing more autonomy. Management must have, therefore, a strong will to delegate certain responsibilities. Modulation of working time can be negotiated, if necessary. For example, use may be made of overtime, partial layoffs, working in teams (evenings and weekends), and timing of vacations. The employees thus accept to take their holidays when there is little activity and, inversely, to work longer hours during the high season.

We have seen, in general, the various means to achieving flexibility. It is, however, an illusion to think that this general approach would be suitable for all companies. Each company has to be considered in its context to find the flexibility that is appropriate to it. To this effect, it is necessary to study carefully its environment and constraints in order to provide personalised solutions. In these conditions, one does not have to be flexible in everything; it is only necessary to be flexible to the extent required by the company's own environment (Carr & Lovejoy, 2000).

Conclusion

After having presented the specifics and problems of short-life-cycle products, we have discussed the literature review based on forecasting demand, inventory management, and the management of production. We have also presented the results of two studies that we have conducted on the printing of an annual guide and the logistical model. In the case of short-life-cycle products, we have discussed the policy of printing twice is lower. In fact, this strategy makes it possible to better control variations in demand and to make the necessary adjustments.

As for the management of the production of short-life-cycle products, it can be based on the following triptych: modular design, delayed differentiation, and flexibility.

If there is any particular insight to be stressed from the present article, it is that the supply chain of short-life-cycle products should be conceived as more than just applying a forecasting, inventory and production techniques and measuring the accuracy of that techniques. Indeed, the supply chain of short-life-cycle products should be viewed as a process comprising the use of multiple techniques and the involvement of multiple departments with the goal to achieve “optimal” supply chain. Although more research is needed to delineate the most preferable supply chain for short-life-cycle products, it is hoped that the present article has provided a foundation on which to base such research and stimulate ongoing discussion of the supply chain of short-life-cycle products.

References


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