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Why Customers Choose Your Product:
a System Dynamics Approach to Customer Choice Modeling

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Abstract
For modeling customer choice in industries in which various suppliers offer a number of products, we found traditional economic modeling methods inadequate. We therefore developed a system dynamics model capturing the important (dynamic) effects. In this paper, the drawbacks of the traditional method are laid out. Then, the model is presented in two stages: first, a generic structure; second, a number of useful enhancements .

Keywords:* *Customer Behavior, Customer Choice, Churn, Market Dynamics, Telecommunications.

Introduction
The liberalization of the Dutch telecommunications industry and the introduction of new products and services created a continuous demand for new modeling techniques that would not be too difficult in daily practice yet would describe customer behavior in an adequate way. TNO Telecom[1] has been involved in the development of these models for about six years now.
Models based on (price) elasticities are straightforward to construct and easy to explain to our clients, but proved to have shortcomings. This led us to develop more sophisticated models using the philosphy of system dynamics. This paper presents the generic structure of these models and discusses a number of useful enhancements.

Churn and the Goal of the Model
In this paper, we will look at the dynamics of a market in which a number of suppliers offer a number of products or services. One of the suppliers is considered to be our *client*. The individual people acting in the market are called the *customers*.

[1] TNO Telecom is the telecommunications department of TNO, the Netherlands Organization for Applied Scientific Research. Before January 1st 2003, TNO Telecom was known as KPN Research, the Research department of KPN Royal Dutch Telecom, the incumbent Dutch telecommunications operator.

The specific focus of the client and therefore of the model is customer *churn*. Customer churn, or simply churn, is usually defined as the rate of movement of people within a system. For our purpose, we will consider churn to be the number of customers switching between suppliers and/or products.

Churn implies large costs for firms. To convince a customer to switch to its product or service, a supplier needs to make a (marketing) effort, implying costs. Also, the longer a customer has a relationship with a supplier, the more profit is generated for the supplier. Therefore, a supplier will want to strike a balance between maximizing the number of customers it has and minimizing (marketing) cost by managing churn. To achieve this, the supplier needs to have a clear picture of the dynamics present in the market. He needs to understand which variables cause people to switch product or supplier.
The goal of the modeling method described in this paper is to provide the client with a basis for his market(ing) strategy by capturing the dynamics that relate directly and indirectly to churn.

Dependency

An important concept in modeling customer choice is the notion of Dependency. A customer's choice is said to be *dependent* if he, voluntarily or involuntarily, bases his choice on previous (historical) choices. Subscribing to a telecommunications service is an example of a dependent situation. A situation in which the customer makes a new choice every time he wishes to buy the product, is called *independent*. A good example of an independent situation is buying bread at the bakery.
While independent situations can adequately be described by other methods, the system dynamics approach is very suitable to dependent situations. The reason for this is that system dynamics can take into account the 'market legacy' – the situation at earlier time points, for example existing market shares or firm image. The system dynamics model in this paper is restricted to products and services (hereafter used interchangeably) with 'dependent' characteristics.
For a full understanding of the advantages of such a model, a more traditional method based on elasticities is discussed first.

Experiences with Elasticities in Customer Choice Modeling[2]

A well-known and widely used technology for modeling customer behavior is modeling using elasticities of demand. The elasticity of demand is the relative change in demand induced by a given relative change in an independent (in most cases exogenous) variable, e.g. price or income. For example, a price elasticity of -0.2 implies that demand will decrease 0.2% when price is increased 1%. Elasticities have many advantages: they are easy to use, easy to estimate, and easy to explain since they are intuitively clear. For these reasons, we often used price elasticities in forecasting future demand for products and services. Usually, the demand for a service before a price change was compared to the demand

[2] In this paper we will only discuss our experiences with price elasticities. Over the years, we have used other elasticities, like the income elasticity (the effect of the income on customer behavior) and cross-elasticities (the effect of the price of product X on the demand for product Y). Our experiences with these elasticities are comparable to our experiences with price elasticities.

afterwards. Because the demand for telecommunications is heavily dependent on seasonal effects and is rapidly growing[3], we mostly used the *adjusted demand*, which was defined as the demand corrected for seasonal effects and an exogenous growth trend. Typically, such a demand function looks like this:

$$D_t = \text{constant} + \text{price effect} + \text{seasonal effect} + \text{exegeneous trend} + \text{other effects}$$

where D_t is the (adjusted) demand for a product or service at time t.

But even with corrections for seasonal effects, exogenous trends, income effects and so forth, we were confronted with some major drawbacks that eventually led us to develop new methodologies. The most important ones are briefly discussed below.

- **Historical Data**. Elasticities are usually estimated with historical data that should not automatically be extrapolated to the present time or new cases. For example, we found a case where the price elasticity was estimated based on an observed change in demand due to a 10 percent decrease in price, say from 1 Euro to 0.90 Euro per entity. This calculated elasticity perfectly described how consumers used to react to the 10% price change. But the marketing department used the same elasticity to calculate the effects of a second strong decrease in price just a few months later. This was clearly a bridge too far: the customers, confronted with a second decrease in price shortly after the first one, did not react in the same way as they reacted to the first decrease in price. In fact, they hardly reacted at all. For the marketing department this was a hard lesson that showed the need for a behavioral model that would take into effect the possible different effects of two or more successive changes in price.

- **The Ceteris Paribus Assumption**. Elasticities rely heavily on the *ceteris paribus* assumption. Ceteris paribus (Latin for "other things being the same") is an economic assumption holding all other variables constant in order to focus on the specified ones (Katz & Rosen (1991)). This works fine in theory, but in practice many variables influence the relationship between price and demand. In the telecommunications industry each week is different from the previous one. New competitors come and go, new services are introduced, etc. The ceteris paribus condition is far too strict to make sense in a practical situation. In order to compensate for the dynamics of the industry, we had to make additional corrections like adding a time series in the elasticities (i.e. making an assumption about the change in the value of the price elasticity over time). But we found these additions to be rather artificial and random. There was no scientific justification and the assumptions could only be verified afterwards.

- **Market Transparency**. Elasticities assume a fully transparent market, i.e. all players (suppliers and consumers) know the exact prices. In real life,

[3] A rapid growth in the demand of telecommunications services was observed during the development of most of our models.

this assumption is violated. Market research shows that in many cases customers have no idea what they are actually paying. We once had a case in which we had to estimate the demand for international calls after a price change. Because at that time we had nothing better, we used a price elasticity that was estimated with historical data. In the same period, a market research was carried out in which the consumers were asked what price they believed they had to pay for a one-minute international phone call. Dramatically, the average price the consumers believed they were paying was an overestimation of nearly 1000% (!)[4]. If customers overestimate or underestimate the actual price of a product or service, their behavior is based on the price they *believe* they pay instead of the price they *actually* pay. A methodology that adequately simulates customer behavior should therefore take into account the fact that the awareness of prices could be very low, especially in industries that are confronted with major price changes in a short period of time.

- **Cause and Effect**. Elasticities do not take into account the underlying causes for customer choice. They only estimate the theoretical division of the market without specifying the causes for this division, or describing the explicit flow of customers between suppliers and products. This is sufficient when we are only interested in a numerical estimation of future demand, but in many cases we want to understand the customer behavior instead of forecast it.

- **Customer Rationality**. Elasticities assume rational customers. That is, if one supplier sets its prices slightly below the market average, it should attract the majority of the customers. However, other (often emotional) variables are not taken into account. That is why in competitive markets, no firm can attain 100% market share.

- **Churn thresholds**. Elasticities negate churn thresholds. Even though another supplier may offer a more attractive product, not all customers are inclined to switch immediately. These thresholds should be modeled explicitly.

These drawbacks, combined with the fact that we only considered markets with 'dependent' characteristics, led us to develop a new method based on the system dynamics philosophy.

[4] Prices had recently declined steeply.

The System Dynamics Approach

The System Dynamics Philosophy

As we have seen, the classic economical estimation method described above suffers from drawbacks. The 'bottom-up' philosophy that is presented here is based on System Dynamics and explicitly models the flow of customers between suppliers and products, including the underlying reasons for this behavior. Working together with market experts, the system dynamicist can use this model to capture the market dynamics. The various causes and effects should be made explicit, to provide a basis for a supplier to improve its market position.
A pitfall would be the complexity of such a model compared to the simple estimation models from economic theory. That is why the simple generic structure of the model is discussed first. So-called enhancements to the model can then be added according to the needs of the situation.

The Model

The Customer Behavior Model (CBM) describes customers' choices between m suppliers ($S_1,\dots,S_m$) who offer n products ($P_1,\dots,P_n$). For the sake of simplicity, it is assumed that each supplier S_i offers all products P_j. This assumption is later relaxed.

The CBM takes the prices of products as a basis, and then applies the effects of different variables to these prices. The outcome in turn affects the customers' behavior on the market.

The CBM consists of two parts. The first part, the Price Cascade, describes the way in which customers perceive and value prices and related (soft) factors. The second part descibes the Customer Loop: it is the way in which customers react to the prices and factors. It also depicts the flow of customers between various suppliers and products in the market.

The Price Cascade

The first part of the model is called the Price Cascade, since it describes how customers deal with prices and related factors and does not contain any loops. The Cascade is made up of different steps, which are set up in such a way, that they can be examined qualitatively and estimated quantitatively individually. In the first step, the actual prices of the products $P_1,\dots,P_n$ are determined for each supplier S_i. Then, in step 2, the prices are adjusted for what the customers *think* the price is, to yield perceived prices. In step 3, the perceived prices are adjusted for factors like quality and service to determine the emotional prices.
Figure 1 shows the Price Cascade. Every variable is actually a multi-dimensional array of all possible combinations (S_i , P_j).

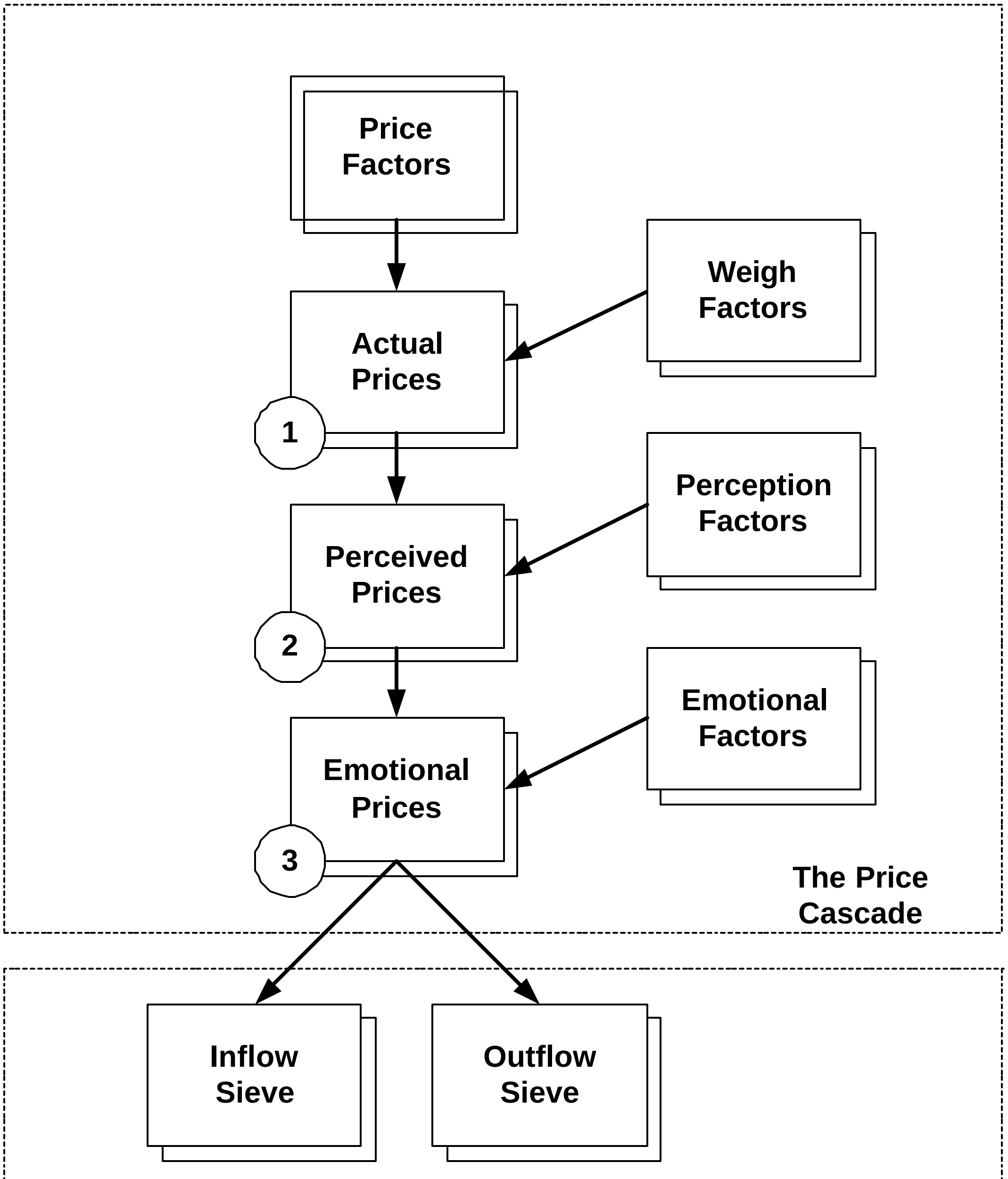

Figure 1 – The Price Cascade

The steps in the Price Cascade

Step 1. In this step, the actual prices are set for each combination of (S_i , P_j). In the telecommunications industry a customer usually pays a monthly subscription rate and an amount based on the usage. In order to reduce the number of prices in our models, we usually take the average monthly bill as the price. The average bill is calculated by a weighted average of the different prices with the average use as weight factors.

Step 2. Ask someone what the price of a certain product is and he will most likely not give the 'correct' answer. Instead, he will report what he *thinks* the product or service costs. Firms tend to influence the idea the customer has about the price of a product – lowering the perception of their own prices and increasing the perception of competitors' prices. Market research has shown that in the Netherlands, the incumbent telecom operator is generally regarded as expensive, where (new) competitors are considered cheap(er), even though the actual price differences are small or even non-existing.

Step 3. Customers base their behavior not only on price. Factors like quality and service can play a big role, especially if these factors differ greatly between suppliers. In this step, an estimation is made for how the customer values the product, expressed in terms of prices. Hereby, 'positive' product aspects tend to lower the so-called emotional price where 'negative' aspects augment the emotional price.

The Price Cascade can be compared to the situation in which you leave your house on a cold winter day. When deciding what clothes to wear, you might first want to check the weather forecast without actually checking or measuring the actual temperature yourself. This forecast can be considered as your *perceived temperature*. When you are outside, the temperature you actually experience (influenced by variables like the wind speed) is called your *emotional temperature*.

Utility

The emotional price has a strong relationship with the concept of *utility* that is often used in microeconomics. The utility is defined as the total level of satisfaction of consuming a particular good or service (Katz & Rosen (1991)). Originally, we used the utility as a measure for the consumer valuation instead of the emotional price. The utility calculation function looked like this:

$$U_j = f(pp_j, of_j)$$

In other words, the utility for product j is a function of the perceived price (pp_j) and some other factors (of_j), like quality and service, that influence the utility. Since utility represents the total level of satisfaction, there should be a positive relationship between the utility level of a certain product and the level of consumption.

The first release of the Customer Behavior Model used the utility of a product as an indication for its desirability. But after working with the CBM for several months, we found that our clients had difficulties with the interpretation of utilities. The major problem is that utility is an economic measure that has no logical interpretation. To show this, consider two products, one with a utility of 10 and one with a utility of 20. Is the second product twice as good as the first one? What does it say about the future consumption of the products? Is this case different from a case of two goods with utility of 5 and 10 respectively? And how can the utility be calculated anyway?

Dealing with these comments, we introduced the emotional price as a different measure of consumer valuation. The major difference is that the emotional price is more intuitively clear. It is easier for our client to ask its customers for their emotional price than for their utility. In the CBM, there is a negative relationship between the emotional price and the level of consumption.

Example

To illustrate the Price Cascade, we introduce an example: consider a market in which three suppliers each offer three products. The weighted prices of the products are as follows:

	P_1	P_2	P_3
S_1	100	100	100
S_2	80	70	60
S_3	110	80	80

Weighted prices

However, a customer survey shows that customers regard supplier 3 as a 'cheap' supplier, causing the perceived prices for S_3 to be 10% lower:

	P_1	P_2	P_3
S_1	100	100	100
S_2	80	70	60
S_3	99	72	72

Perceived prices

Now, assume the quality and service of supplier 1 are significantly better. Market research shows that S_1's brand and image are worth 20%. This leads to the following emotional prices:

	P_1	P_2	P_3
S_1	80	80	80
S_2	80	70	60
S_3	99	72	72

Emotional prices

The Customer Loop

After the Price Cascade, the (multi-dimensional) variable 'emotional price' results, which is used in the Customer Loop to compare the different combinations (S_i , P_j) and determine customer behavior.

The Customer Loop Model is presented below in two stages. First, the basic model is discussed. This model is simple and robust, and serves as a generic structure. A single, though multi-dimensional loop, the Closed Market Loop, describes the customers as they churn between different suppliers and/or products.
Second, a number of possible enhancements for the basic model are presented. The enhancements add loops as well as in- and outflow structures to the system.

Depending on the particular case, these enhancements should be used with the basic model to suit the client's needs.

The basic model is shown in Figure 2.

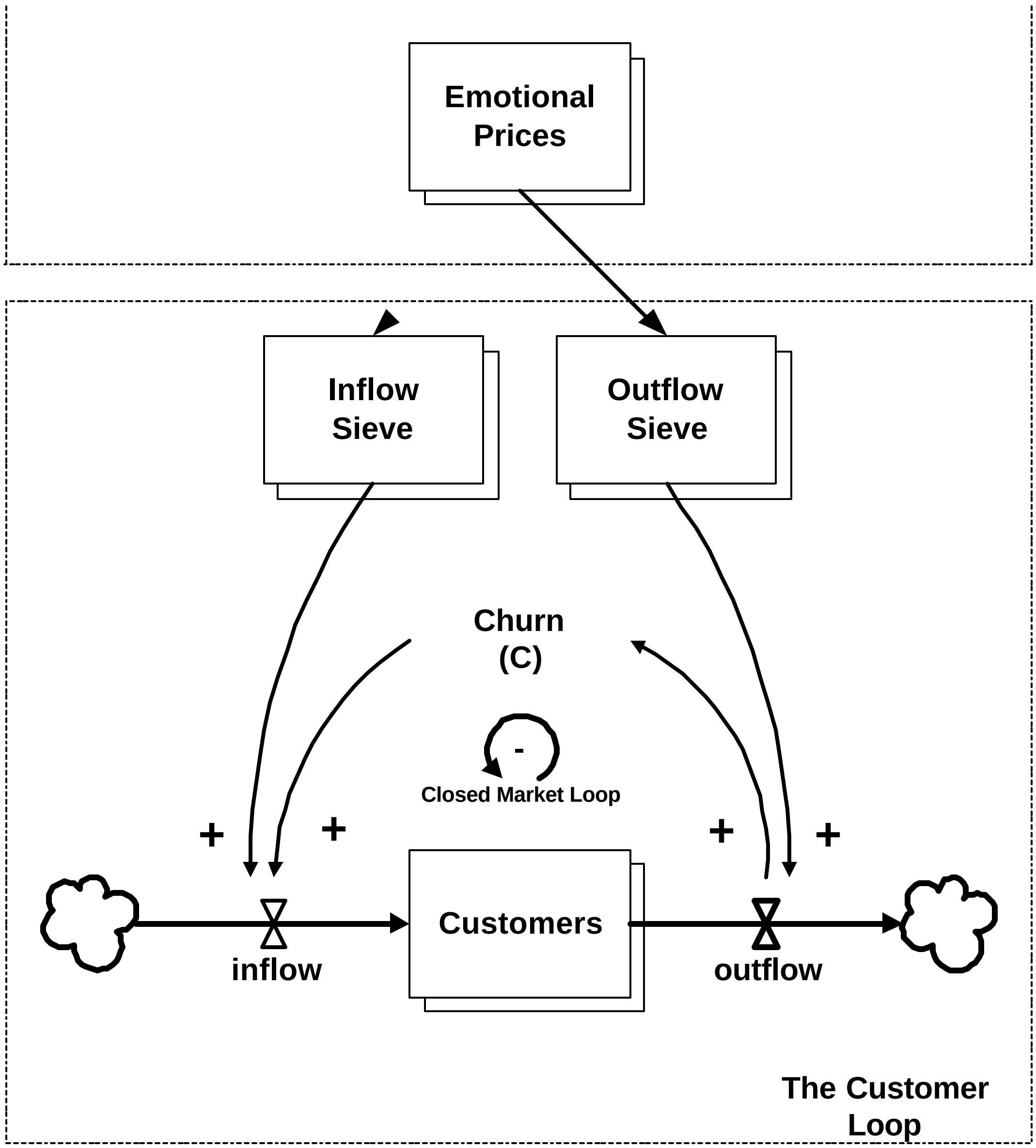

Figure 2 – The Customer Loop

All variables, except C, are calculated for every (S_i , P_j) combination.

The main part of the basic model consists of the customer flow through the system. Customers that are unsatisfied with their supplier and/or product flow out of the customer base. The outflow is determined by the so-called Outflow Sieve. These customers (represented by the quantity C) are said to be churning and will then choose a new combination of supplier and product, flowing into the customer base again. This inflow is influenced by the Inflow Sieve.

The Outflow Sieve is nothing more than a table with, per (S_i , P_j) combination, the fraction of customers abandoning that combination. One reason for which customers switch away from a supplier or product is that they are unsatisfied with it. For example, the service may be poor or the bill might contain errors. Another reason would be the ending of the subscription period. Telecom services are typically offered with a one-year subscription.
The Outflow Sieve thus captures dissatisfying and cancellation effects.

The Inflow Sieve is a table with the fractions of all churning customers who choose a particular combination. It captures the choice process of customers who generally base their choice on positive aspects of a supplier or product. The Inflow Sieve takes satisfying effects into account.

Tuning the Customer Loop boils down to determining the ‘correct’ values for both sieves, based on market research where possible.

Example (continued from above)

To compute the effect of the Emotional Price (EP) on the Inflow Sieve (IS), we use the following formula:

$$\mathrm{IS}_{\mathrm{i,j}} = \frac{e^{a \cdot EP_{i,j}}}{\sum_i \sum_j e^{a \cdot EP_{i,j}}} \quad \text{with -1} \quad \text{á} \quad 0.$$

This formula has the advantage that lower prices lead to higher inflow. The parameter á denotes the relative influence of price differences on the customers' behavior. If á = 0, they don’t care at all about price differences and will randomly choose a (S, P) combination. If á = -1, the customers are very sensitive to differences in price and will choose the cheapest combination. Generally, á should be set close to 0.
Applying the formula with á = -0.05 yields:

	P_1	**P_2**	**P_3**
S_1	0.09	0.09	0.09
S_2	0.09	0.14	0.23
S_3	0.03	0.13	0.13

Inflow Sieve (IS)

This should be interpreted as: 9% of new customers or churning customers will choose combination (S_1 , P_1). Note that the sum of all the fractions, barring rounding differences, is 1.

For the sake of simplicity, assume that in every time period, 5% of the customers abandon their current (S_i , P_j) combination because their subscription period ends. This effectively cancels the effect of the emotional price on the outflow, and the Outflow Sieve becomes:

	P_1	P_2	P_3
S_1	0.05	0.05	0.05
S_2	0.05	0.05	0.05
S_3	0.05	0.05	0.05

Outflow Sieve

This should be interpreted as: every time period, 5% of the customers who currently have combination (S_1 , P_1) will abandon it. The numbers in the Outflow Sieve are independent and therefore need not sum to 1.

If we assume that there are 3000 customers, and that S_1 possesses a market share of 100% at t=0 (e.g. S_1 is the incumbent operator at the liberalization of the market) and an equal initial division of the customers between the three products, we get:

	P_1	P_2	P_3
S_1	1000	1000	1000
S_2	0	0	0
S_3	0	0	0

Customer Base at t=0

Now, assuming that the sieves do not change over time, we now have enough data to run the model. Using these simple assumptions, the system will convert to an equilibrium, due to the presence of only balancing loops. In Figure 3, two of the nine combinations are shown.

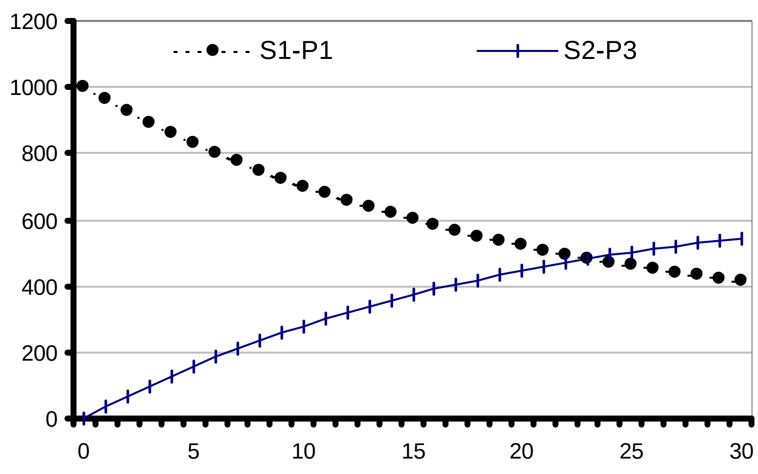

Figure 3 - Number of customers for two supplier-product combinations

In the basic model, a few important assumptions are made. First, the market is assumed to be closed, meaning that no customers enter or leave the system (i.e. no new customers are 'born' and none 'die'). Second, all customers choose exactly one supplier-product combination. Third, the ‘amount’ of the product or service that the customer purchases, is ignored, and can be estimated separately if needed.

Enhancements

We have tailored our model to various specific cases by adding model *enhancements* to the basic structure. Each enhancement adds to the model, or relaxes an assumption. However, adding enhancements makes the model more complex. That is why it is a good idea to make a checklist of possible enhancements and to determine together with the client which ones to apply.
In various models, we applied the following enhancements:

1. **Allowing Physical Customer Changes.** The assumption that no customers enter or leave the model is relaxed. Customers then leave the system proportionally. Customers enter the system using the Inflow Sieve. Adding this enhancement is a good idea if the size of the market varies over time.
2. **Product Churn versus Supplier Churn.** In certain markets, thresholds exist that diminish the churn between suppliers but not the churn between different products of the same supplier. For example, changing banks might imply changing your bank account number, which is awkward. To capture this effect in the model, the variable C should be made multi-dimensional, and the inflow sieve should take into account where the customer is churning *from*.
3. **Block entry for certain products and/or suppliers.** In certain markets, regulations prohibit the churning to certain products or suppliers for a certain time period. For example, the telecom market in the Netherlands was liberated in 1997. From that moment on, customers were able to choose their own telecom operator; before that, they were restricted to the incumbent operator.
4. **Multiple products.** Here, the assumption that every customer chooses precisely one supplier-product combination is relaxed. Suppliers might offer complementary products, perhaps offering a discount or a package deal. An example of this is the energy market in the Netherlands, in which many suppliers offers both fuel and electricity services.
5. **General effects.** It might happen that certain products or suppliers become more popular or unpopular in time. A product might be ‘hot’ causing more customers to choose that product. A supplier might receive bad media attention, or be the victim of a boycott. A general parameter can capture these effects.
6. **Seasonal effects.** The sales of products or services may be season-dependent. For example, gas sales are higher in winter than in summer. Seasonal effects can be represented by an additional factor.
7. **Endogenous Prices.** If a firm has enough knowledge of its competitors, it can try to forecast the reactions of competitors by making their (pricing)

decisions endogenous in the model. Loops should be added, increasing the dynamics in the system.

8. **Service Usage.** This enhancement takes into account that the better the deal offered by a supplier, the more a customer will purchase. For example, a lower price of telecommunications services may cause the number of calls to go up.

Tailoring and Implementing the Model

The CBM is a generic model. This implies that its structure can be used in a variety of settings. However, when a specific case is modeled, care must be taken that the model describes the real situation adequately. To achieve this, the modeler can tune the individual parts of both the Price Cascade and the Customer Loop. The client should provide the modeler with qualitative and quantitative insights and data about the market. For example, the set of perception factors can be determined in cooperation with the supplier's marketing department. Or the Outflow Sieve might be tuned according to the outcomes of a customer survey asking customers why they canceled their subscription.
In any case, the client should be involved in this process. Sterman (2000) states that "…a main purpose of modeling is to design and test policies for improvement. To do so, the client must have confidence that the model will respond to policies the same way the real system would." This is the reason that the model is designed to capture individual effects that can be understood and measured by the client.

Final Remarks

The CBM provided us with a relatively simple, but powerful methodology that can be used in many cases with only small adjustments for each specific case. We have used it in cases for incumbent operators, but it has also proved to work for smaller market players. For TNO Telecom and its clients, the CBM is the perfect compromise between a model that sufficiently captures all relevant effects and a model that is simple and robust.

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