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Simulations for Planning Dresdner Bank's E-day

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Confronted with the approaching introduction of euro coins and notes, Dresdner Bank's branches had to consider that the cash related transactions between 17th December 2001 and 28th February 2002 would rise much above the normal level. On top of the regular business, they had to cope with an unknown amount of exchange transactions of Deutschmark into euro. To avoid chaotic situations in the branches and high extra costs, the branches had to prepare themselves and had to decide on a couple of measures available. The paper presents how four different scenarios on customer behaviour are developed, and how these scenarios are linked with a queuing simulation model which was able to show the impact of different assumptions on the situation in the branches during the changeover period. Simulation and analysis results showed that Dresdner Bank's branches were facing some challenges during changeover period. Absolute chaos on broad front was however pretty unlikely.

Key Words: Euro, Queuing Simulation, Scenario Technique, Planning, Decision Making, Bank Management

1 The challenge of introducing euro banknotes and coins on 1st January 2002

Since 1st January 2002 the euro is the official means of payment in Germany as well as in 11 other States of the European Union. Despite a partly euro sceptical opinion of the German people throughout 2001, the introduction of euro banknotes and coins on 1st January 2002 was a great success (European Commission, 2002). The acceptance of the new money was high and by the mid of January 2002 almost nobody tried to pay with German marks anymore although they could have done until 28th February (European Commission, 2002).[1]

The smoothness of the changeover period was not an obvious task. Changing all the circulating coins and bank notes in 12 European countries at the same time was one of the biggest challenges the organizations involved had ever faced. 14.5 billions bank notes had to be printed – if piled up, a tower with a height of at least 1.200 km would result. 50 billions coins had to be stroked – enough to load more than 8.000 forty-ton lorries (Deutsche Bundesbank, 2001). Two third of this tremendous amount of money had to be distributed to millions of bank branches, post office counters, wholesalers and retailers, shops and agencies by 31st December 2001.[2] All these actions had to be taken

[1] In Germany the so-called "dual circulation period" ran from 1st January to 28th February 2002.

[2] 1/3 was needed as reserve stock.

so that 300 million European could welcome the new year 2002 and the new notes and coins simultaneously. A lot of planning and preparation was necessary for all the organizations involved to ensure a smooth changeover process. As one of the biggest private banks in Germany, Dresdner Bank AG started a large-scale project at the beginning of 2000. One part of this project was to help the branches to plan some measures suitable to cope with a great rush expected for the last days of December 2001 and the first weeks of 2002. Having delivered the euro coins and notes to the branches – a process the European Central Bank (ECB) called frontloading and started in Germany on 1st September 2001 – a lot of work was done, but the most challenging part of the changeover process for the branches was still to come.

Dresdner Bank alone had in over 800 branches 900 automatic cash safes and 1,200 cash dispensers. All these had to be filled with euro notes in time. Approximately 2,250 cash desks needed to be provided with euro coins. And 1.5 million euro starter kits with coins worth 20 Deutschmark (DM) had to be distributed to customers starting on 17th December 2001. Planning all these activities was not an easy task due to a tremendous amount of detail complexity. Uncertainties were however relatively low. Conversely, the planning of measures for the branches revealed to be very complex. Due to high uncertainties, lack of data and some dynamic complexity it turned out to be very difficult to forecast the impact of the introduction of euro coins and banknotes on a branch's business from 17th December 2001 until 28th February 2002.

Basically it was not necessary to change DM into euro explicitly in a bank's branch as trade and industry had committed themselves to accept DM for everyday buying and give euros as change (Deutsche Bundesbank, 2001). The most optimistic scenario therefore was: nothing happens at all, same procedures and business as last year. This idealistic view was however very unlikely to become reality. Nobody in the project team was so optimistic to vote for the ideal scenario. Everybody thought of reasons for customers to visit a branch, especially for older customers who are used to come to a branch for updating their savings book. It seemed to be very unlikely that this long established habit would suddenly change when the euro was introduced. On the contrary, the possibility of changing DM into euro at the same time could have been even a stronger incentive to visit a branch. Another common argument was that some customers would remember that they still had foreign notes and coins like for example Franc or Lira that they would not be able to spend any more. People would come into a branch and change the money before it would be impossible to do so. A third argument was the following: if the euro was to be quickly accepted everywhere, there could be a lot of people who would have too much German marks left and who would not want to spend them in shops anymore. They would then be forced to visit their bank's branch to get rid off them. And last but not least, some people would not be satisfied with all the information provided through the media and would want to ask the cashier personally.

Despite all the uncertainties, the project team's members were convinced that cash transactions and workload in branches would rise during the changeover period. Therefore measures had to be planned as the bank managers did not want to see long queues, long waiting times, and a lot of angry customers. They feared a strong negative impact on Dresdner Bank's image and, as a consequence, a damage in future sales. On the other hand the additional costs caused by issuing euro banknotes and coins should have been minimized and the sale of other bank products should not have suffered from chaos in the branches. What could be done? During the project a considerable number of ideas and measures were collected. The following section gives a brief and systematic overview of the suggestions.

2 Possible Actions for Dresdner Bank Branches

Contrary to the first indications, it appeared that a Dresdner Bank's branch would have to cope with challenges during the changeover period. Of course almost everybody thought of opening extra cash desks or extending the opening times e.g. in the morning or evening or over the weekend. However these kinds of actions could not be more as a last resort. Surely they would have had an effect, but they simultaneously would have been very expensive and really difficult to implement.

Installation of extra counters for example was likely to fail in many branches because of missing free space in the counter hall. If there were no space restrictions, then the automatic cash safe could have become the bottleneck. Usually one safe is able to provide cash for two or three counters maximum. If the limit were reached, a new cash safe would have to be installed. This, however, would have been so time consuming and expensive, that lots of severe reasons would be needed to allow its implementation.

While it did not seem to make sense to extend the number of regular branch counters, the installation of additional counters for special tasks, e.g. the giving out of euro starter kits, was worth thinking about. These specialized counters with limited service offers would be able to extend service capacity in branches where a great rush was expected. Nevertheless, the installation and operation of specialized counters was relatively costly as well. Therefore it seemed to be reasonable to consider other measures that were not so cost-intensive.

Before trying to extend the capacity by installing new counters, branches should make sure that the existing ones would always be on duty. Counters that were not normally used had to be opened. For that, enough employees would have been made available to prevent the counter from being closed during necessary breaks. For taking the load off the cashiers a back office could have been installed which would have been able to do preparatory work as well as special things such as fanning out the banknotes or handling big payments.

Maximization of the available capacity as discussed above was one important task in preparing Dresdner Bank's branches for the DM-euro changeover. Trying to prevent the customers from coming into a branch in the most critical days would have been, however, even better. For reaching this goal the suggestion was made to address and inform in small branches customers individually in November and December 2001 while handling their bank transactions. In large and more anonymous branches posters could be displayed. Intensive marketing for home banking, credit or bank cards and other cashless payment systems were discussed as promising additional measures. As additional measure, it was also suggested to fix dates for sales talks to make time and capacity planning easier and help to achieve the sales targets.

Customers that would come into a branch despite all the measures discussed above should be guided as well as possible. This could be done by putting up additional direction signs or installing an information counter or providing specialized service staff walking around. Offering waiting customers tea or coffee as well as cakes and pastries could help to ensure a good atmosphere. Table 1 summarises again all the measures discussed above.

Categories of Measures	Measures	Practicability	Effect on Costs
Guiding customers	Optimisation of direction signs	simple	very little
	Installation of an information counter	simple	medium
	Service staff in the counter hall	simple	medium
	Offering tea or coffee and cakes and pastries	simple	little
Reducing the need of capacity	Informing and influencing customers	simple	little
	Intensified marketing for home banking	simple	little
	Intensified recommendation of cashless payment	simple	little
	Fixed appointments	simple	little
Increasing capacity	Installation of a back office	simple	medium
	Use additional cashiers	medium-difficult	medium to high
	Opening normally not used counters (incl. cashiers)	simple	medium to high
	Expanding opening times (incl. cashiers)	medium-difficult	medium to high
	Installation of special cash desks for special services (incl. employees)	difficult	medium to high
	Installation of additional counters (incl. automatic cash safe and cashiers)	very difficult	very high

Table 1: Possible measures for a bank's branch during the dual circulation period

Taking into account that the objectives customer satisfaction, image safeguarding and costs minimization are pretty much incompatible, it was necessary to select carefully which measure was appropriate for which branch. The prerequisite for a rational decision however was information on the expected seriousness of the situation between 17th December 2001 and 28th February 2002. The estimations available, however, seemed to be of low reliability and certainty. Therefore the project team decided to gather additional information and use simulation models for improved forecasts. Especially two areas for further information improvement were identified:

- On the one hand, information should be made available on the actual use of cash transaction capacity and on additional resources that could be used.
- On the other hand, scenarios should be developed showing when how many customers will probably come to a branch and try to change cash – in addition to the normal business.

To make the additional information available Dresdner Bank's accounting database was queried and two simulation models were developed. The first simulation model supported the development of the scenarios of customer behaviour (see following section 3). Based on these scenarios the second simulation model – a queuing simulation model – was used to determine on a day-by-day basis the consequences for a specific branch (see sections 4 and 5). Variables of interest were for example the percentage of capacity used, the length of the waiting line, or the amount of critical days i.e. days with high overload. For each branch a report was created that brought the different pieces of information together and served as a basis for improved decision making.

3 Scenarios of Customer Behaviour

To deal with uncertainties connected with the forecast of customer behaviour the project team decided to work with four different scenarios:

- Scenario A was based on the idealistic, but unrealistic assumption that no change compared with the previous year will occur. Although everybody believed scenario A to be completely improbable to happen, it was important as a starting point for the development of the other scenarios (B to D).
- Scenario B was regarded as being optimistic.
- Scenario C assumed that several problems would occur.
- Scenario D was the worst-case scenario where almost everything would go wrong.

With these four scenarios the uncertainty about the future development was not hidden but structured and therefore for all people involved less frightening (Ringland, 1998).

Because it was necessary to support the decision on the appropriate measures for each Dresdner Bank's branch individually, branch specific scenarios also had to be developed. Considering the fact, that Dresdner Bank had over 800 branches in Germany, it was clear, that this could not be done manually. Automated routines had therefore to be developed to specify the scenarios.

Basis for scenario A were the actual cash transaction data collected between 18th December 2000 and 23rd February 2001. The number of transactions was counted on a daily basis for three customer groups separately: private customers (PK), corporate customers (FI) and small enterprises (GE). Additionally eight transactions types were distinguished:

- KKEZ: current account pay in
- KKAZ: current account pay out
- SPEZ: savings account book pay in
- SPAZ: savings account book pay out
- SPN: updated print of a savings account book
- SOAK: buying foreign currencies
- SOVK: selling foreign currencies
- HGA: hand over of packed coins

The reason for the disaggregation of the cash transactions was the belief that there were significant differences in the transaction times between the categories.[3] The result of the data collection effort is illustrated in Figure 1. It shows as an example a very small part of the whole picture: the amount of a branch's cash transactions during one single day (arbitrarily chosen from December 2000).

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[3] Although the differences in the transaction times later actually turned out to be significantly different, the impact on the weighted aggregated distribution of transaction times was quite small (see Figure 14 on p. 16). The disaggregation nevertheless proved to be useful because of its ability to increase the project team members' confidence in the model.

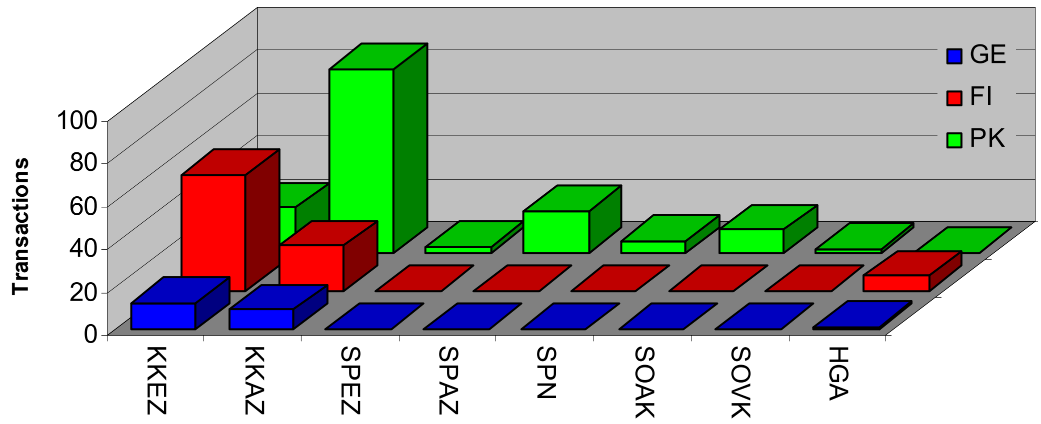

Figure 1: A branch's transaction dataset for a single day

To create Scenario A the data collected from 8th December 2000 to 23rd February 2001 was then mapped to the changeover period. For example, the number of transactions during Monday, 18th December 2001, was equated with the data from Monday, 17th December 2000. Besides that, estimations for two transaction types that were not documented in the IT systems, had to be added. The one transaction type concerned was direct exchange i.e. the customer gives the cashier 50 DM and gets back 25,56 €; the other type was the customer's wish to have access to his safe-deposit box.[4]

Scenario A was – as already pointed out – believed to be unrealistic. It was however very important to give the experts the possibility to validate the queuing simulation model by comparing the output with their last year's experience. And it also was the starting point for the development of the scenarios B to D. B, C, and D changed - compared with A - the following parameters:

- the cumulated number of cash transactions between 17th December 2001 and 28th February 2002
- the distribution of the cash transactions over the changeover period
- the composition of the transactions regarding customer groups and transaction types

A euro specific new task for the cashiers without any equivalent in 2000/2001 was the distribution of the starter kits.[5] All in all, Dresdner Bank's branches had to find a taker for 1.5 millions of such kits. Because everybody in the project team was convinced that customers demand would be large enough to sell them without great problems, no differentiation between the scenarios was made. Therefore all scenarios had the same distribution of the transactions over time assuming that the starter kits would be sold out by end of December 2001 (see Figure 2).

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[4] Abbreviations for the additional transaction types: KSF = transactions involving customer needs to go to their safe-deposit box; ZZW = direct change of marks into euro.

[5] Abbreviation: SK = selling euro starter kits.

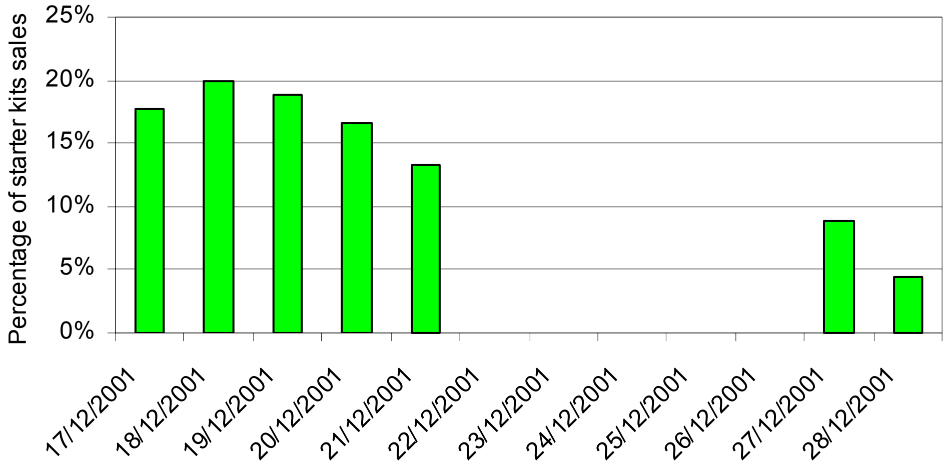

Figure 2: Distribution of euro starter kits sales

While it seemed to be relatively easy to plan the additional workload caused by the sale of euro starter kits, it was far more difficult to predict customers' behaviour in January and February 2002. In a brainstorming session held in October 2000 a broad range of factors were identified that were thought to be able to influence the customers' wishes and needs to come to a Dresdner Bank's branch. Figure 3 shows the result of the brainstorming as a policy function diagram (Morecroft, 1994).

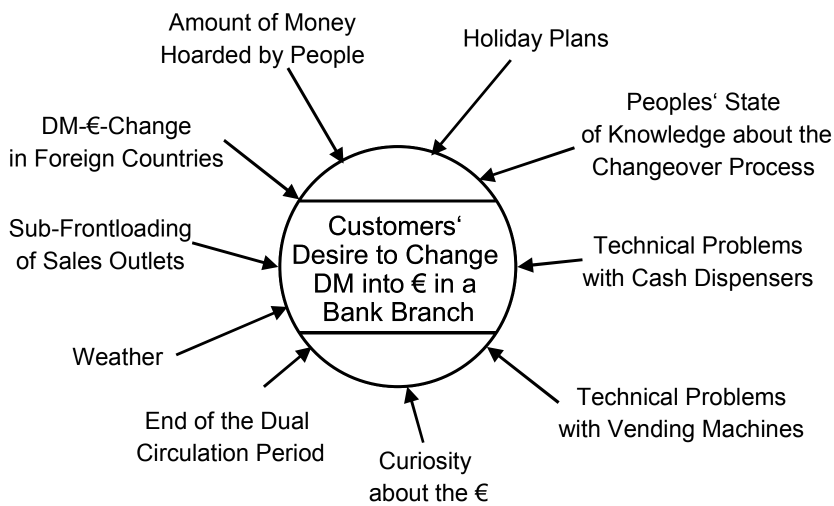

Figure 3: Policy function diagram for the peoples' desire to change DM into euro

Most of the factors depicted in Figure 3 were seen as exogenous inputs, what in a System Dynamics terminology means, that they are not part of feedback loops. (Forrester, 1961). Nevertheless they were believed to have a more or less strong effect on the exchange dynamics. Quantification, however, turned out to be quite difficult and the team members mental models were not fully congruent. Therefore a small simulation model of the generic exchange process was built to get a rough idea of the dynamics. Figure 4 shows the main stocks and flows as well as the main feedback loops.

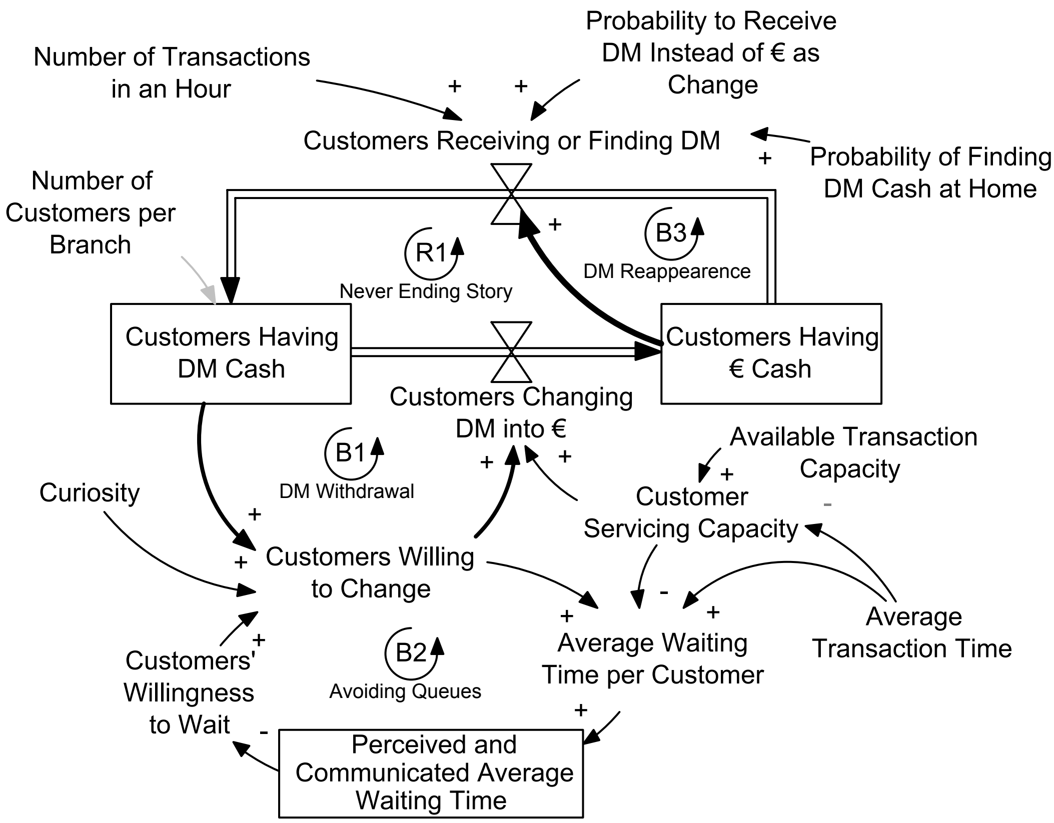

Figure 4: Model supporting scenario development[6]

The balancing feedback loop B1 describes the basic exchange process. Customers having DM coins and notes become willing to change their cash into euros, go to their branch and perform the transaction moving themselves into the stock of customers that have only euro coins and notes left. This basic loop – named "DM Withdrawal" – was supposed to dominate at least in the long run. Finally, the values for all involved variables would be zero by nature as with the end of the dual circulation period, DM would not be accepted as a means of payment anymore. However, some limiting factors and loops had to be considered. Limited customer servicing capacity is on the one hand able to constrain the flow of customers changing DM into euro.[7] The resulting queues on the other hand bring the avoiding-queues loop (B2) into life.

However, the model's main idea was to take into consideration that the process of changing DM into euro was not irreversible: Customers were thought to receive or find DM coins and notes once more after having been in a branch and changed their DM cash into euro. Consequently Figure 4 shows a backflow of customers finding or receiving DM to the stock of customers having DM cash.[8] This backflow creates a positive feedback (R1) loop that is marked with thick arrows in Figure 4 and labelled

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[6] For further information on the meaning of the symbols and the modeling approach used in Figure 4 refer to Sterman (2000).

[7] The rate equation uses the MIN-function to express this limitation: Customers Changing DM into € = MIN (Customers Willing to Change , Customer Servicing Capacity).

[8] The equation is: Customers Receiving or Finding DM = Customers Having € Cash * Number of Transactions in an Hour * Probability to Receive DM Instead of € as Change + Customers Having € Cash * Probability of Finding DM Cash at Home

"Never Ending Story".[9] There was no lack of reasons why this could have happened. In the brainstorming meeting for example were the following arguments listed:

- problems with the frontloading (branches) and sub-frontloading (shops)
- badly informed small businesses
- temporary rejection of the euro through the people
- technical problems with vending machines
- technical problems with cash dispensers

The base run portrayed in Figure 5 was generated using the parameter values listed in Table 3 and displayed in Figure 30 in appendix A.

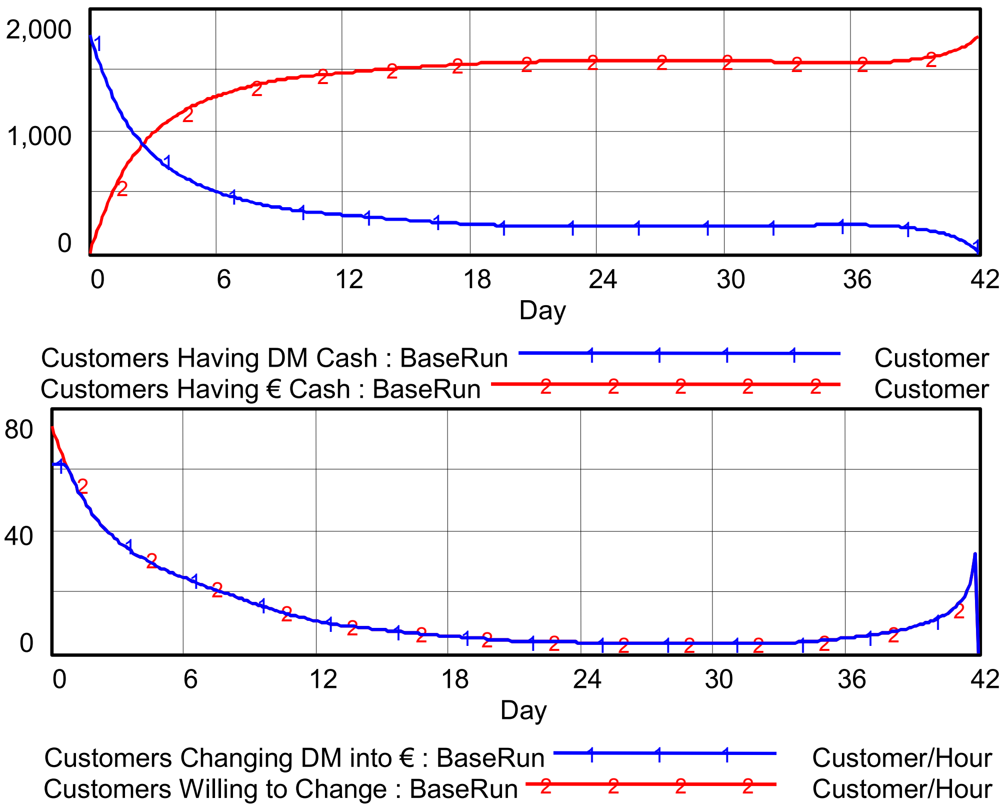

Figure 5: Base run dynamics

The base run dynamics during the first 18 days are determined by the balancing feedback loop B1 dominating in these days; the more customers however have changed all their DM coins and notes into euro, the weaker becomes B1 and the more the reinforcing loop R1 comes into action. After some 18 days, a temporary equilibrium is reached – unfortunately far away from the desired one with all DM coins and notes withdrawn from circulation. The final state, in which everybody use exclusively euro cash, is only achieved at the end of the dual circulation period where DM acceptance draws to an end. DM coins and notes eventually become useless for people and have to be changed, which causes once more higher workload than normal in the branches during the last days of February.

[9] The backflow of customers into the level "Customers Having DM Cash" introduces not only the reinforcing feedback loop R1, but at the same time the balancing feedback loop B3.

The lower time chart of Figure 5 shows the effect of limiting customer servicing capacity. In the very first day more customers want to change their cash than could be serviced. Queues are certain to occur during this first day. Because of the short time period with overstrained capacity, however, the “Avoiding Queues” loop is weak. Running some simulations with varying probabilities that customers receive DM instead of € as change when shopping confirmed the assumption that the “Never Ending Story” loop could highly endanger the whole changeover process. The line marked 2 in Figure 6 shows what everybody in the team feared: high workload for the cashiers throughout the changeover period with peaks at the beginning and at the end.

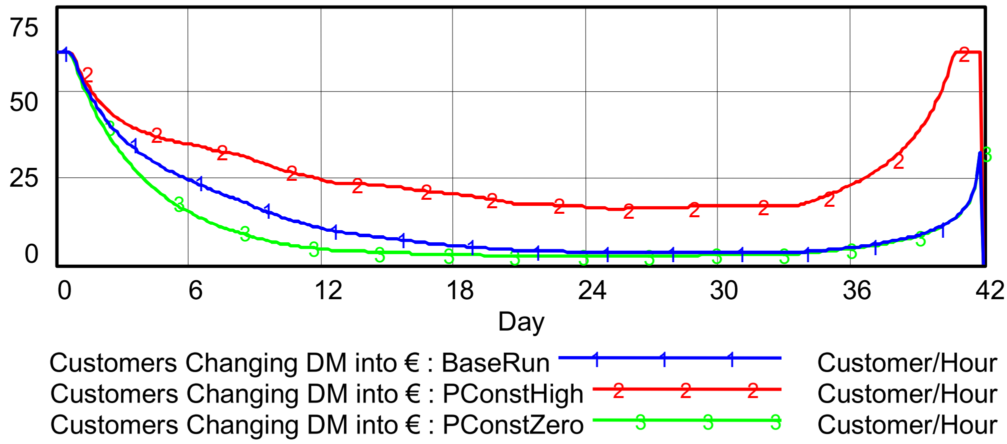

Figure 6: Impact of variations in the probability of receiving DM instead of euro

The other variable that turned out to be highly sensitive was curiosity. In absence of curiosity – an only theoretical scenario – it was assumed that the customers would come equally distributed into the branch to change their cash. As shown in Figure 7 this behaviour however would result in increasing workload with a peak at the end of the dual circulation period due to the never ending story loop. On the other hand the higher curiosity was assumed to be at the beginning, the more customers would come to the bank’s branches in the first few days of 2002 causing a period of permanent rush.

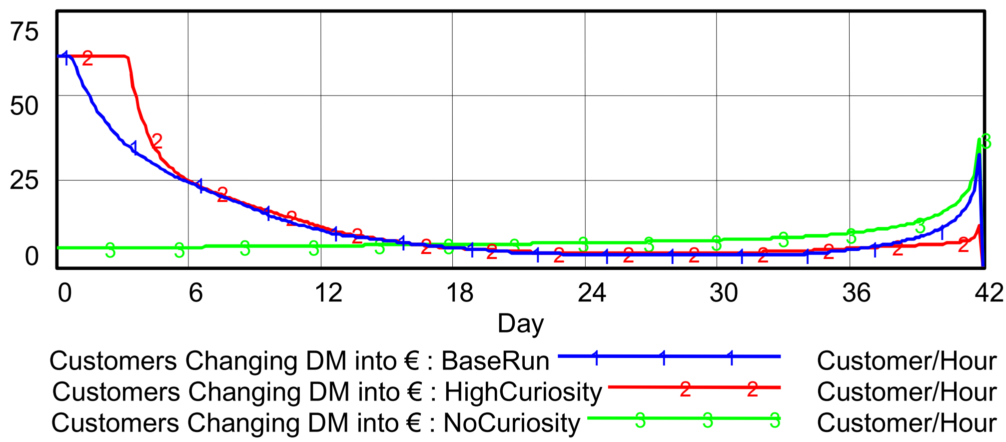

Figure 7: Impact of variations in curiosity

Because not all the factors that were identified in the brainstorming session (shown in Figure 3) had been included in the model, the scenarios of customer behaviour were not directly based upon the simulation output. Instead, a group of experts was asked to give their estimations having to their disposition a description of the three scenario environments and the simulation results. What they had to estimate was firstly the percentage of cumulated transactions on top of 2001's numbers, secondly the distribution of theses additional transactions over the two-month time span and thirdly the probability for a scenario becoming reality. The following scenario descriptions were given to the experts, each of them representing a specific setting of factors found in the brainstorming session.

- In scenario B very little problems will occur in all the areas relevant for putting euro banknotes and coins into circulation. The sub-frontloading will be widely used and well-done and therefore big shops as well as small shops will have enough euro cash for change. The cash-transporting companies will be well prepared and able to cope with the challenges imposed to them. Consequently supplying the bank branches and shops with euro will take place without significant problems and removing the DM cash will be done just as easily. As a result the probability that customers would receive DM after having got rid off all their coins and notes will be very low. The public will be well informed and understand that it will be no problem to pay with DM in January and February. ECB, Bundesbank, government and all public and private banks will have made a lot of publicity about the new currency with the result that the euro will be well accepted by the people and everybody will be pretty curious about the new coins and notes. Besides that, the advertising campaigns during 2001, to reduce the amount of money hoarded by private individuals, will be successful as well. The amount of DM coins and notes that will have to be changed will therefore be relatively low. Even for the DM circulating abroad, hardly anything will flow back to Germany, as numerous places to change the money will have been installed. All cashless payment systems will work smoothly, so there will be no need to pay by cash. Hardly any problems will occur with the other technical systems i.e. cash dispensers, vending machines etc.
- In scenario C several difficulties will occur. However, these problems will not be really serious. As a result of too much bureaucracy sub-frontloading will be well accepted only by large shops and trade companies with a network of branches. A significant percentage of small and medium stores therefore will try to collect their euro cash change at the bank's branches just when they will need it (that is 1^{st} or 2^{nd} January 2002). The probability to get once more DM cash will be consequently higher. Furthermore, the public is assumed to be less well informed, more sceptical and more interested in personal information through bank clerks.
- Scenario D is the worst-case scenario. Problems will arise all along the line. Compared to C the sub-frontloading will be even worse. A lot of stores will not have enough euro cash and therefore will be forced to give DM coins and notes as change. The situation will be even made worse by the people that will be badly informed. A feeling of insecurity and anxiety will be wide spread. Furthermore, the advertising campaigns during 2001 to reduce the amount of money hoarded by private individuals will be an almost complete failure. Customers will bring huge amounts of coins to the branches in January and February 2002. The haulage firms will be overstressed and badly performing their tasks due to some spectacular robberies precautions, which will slow down all the processes and increase the bottlenecks.

Final estimation of the scenario parameters was done in a workshop in April 2001. Although each expert had of course his own opinion, the discussion ended with a consensus. The joint estimation was:

1. Plus 40 % in cumulated transaction for scenario B, plus 60 % for scenario C and plus 150 % for scenario D (seen in relation to scenario A).
2. A distribution of the additional transactions over the two-month time span as shown in Figure 8.
3. A probability of 45 % that scenarios B or C will become reality and a probability of only 10 % for scenario D.

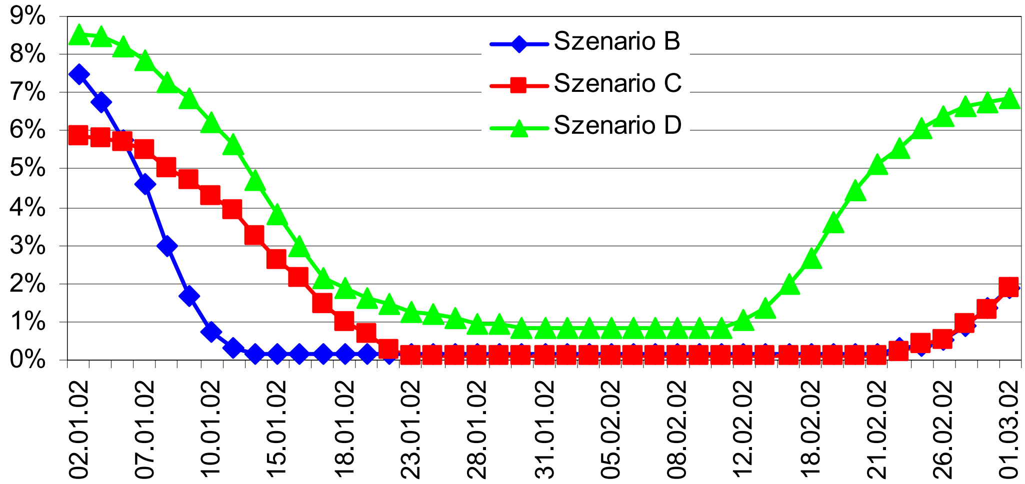

Figure 8: Distribution of additional transactions during the changeover period

Another workshop was used to discuss changes in the mixture of transactions due to the specific needs of customers during the exchange period. In this workshop was, among others, for example the following argument discussed. Because 12 national currencies would vanish the need for changing Deutschmark into foreign currencies should go down. As a result the percentage of this transaction type had to be reduced for scenarios B, C and D compared with scenario A. This kind of analysis and estimation was done much more deeply. However, because of only relatively small differences in the transaction time distributions for the 12 transaction types, it later turned out, that the effect of changes in the transaction mixture had very little impact on the simulation results. Therefore it does not seem to make sense to go here further into detail.

The result of the scenario development was ultimately an hypothesis, which defined when and how many additional transactions will be required by customers in a specific bank branch during the changeover period. Figure 9 and Figure 10 give an example for the private customer’s transaction mix for two different days.

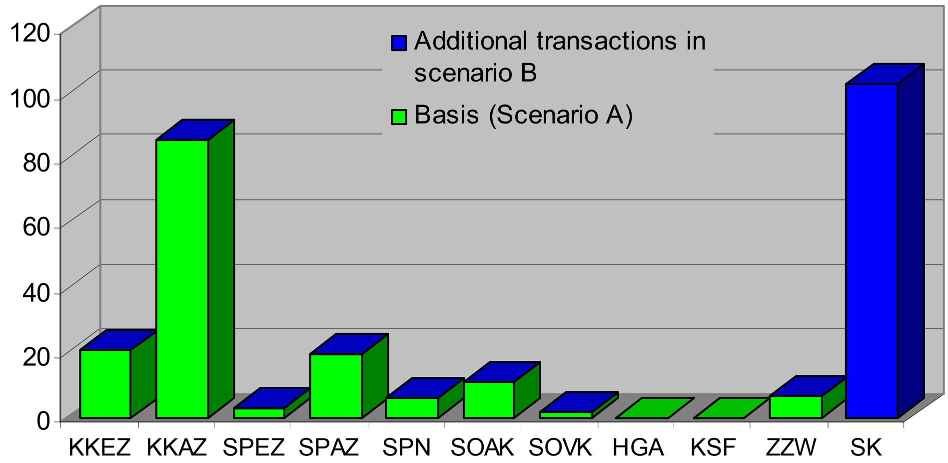

Figure 9: Private Customers' transaction mixture for a day end of December

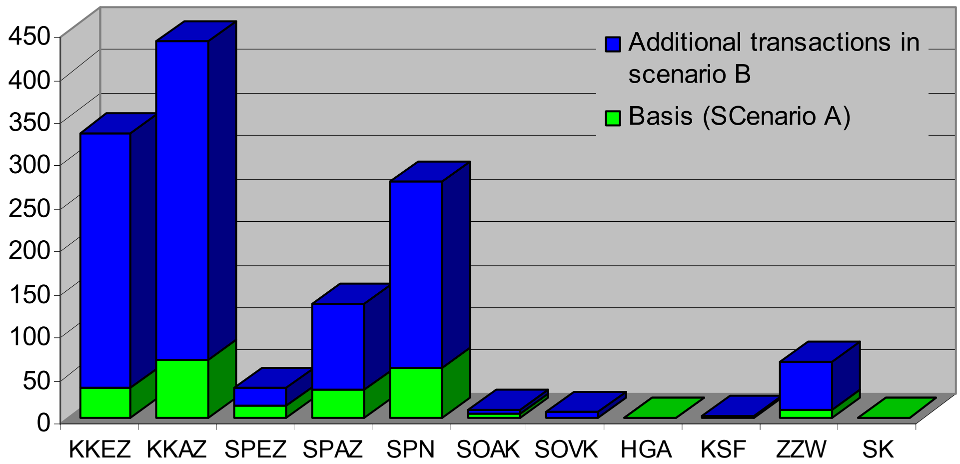

Figure 10: Private Customers transaction mixture for a day in early January

To show the consequences of each of the four scenarios, the queuing simulation model described in the next section was used.

4 The Queuing Simulation Model for Dresdner Bank's Branches

The cashier's regular business in a bank branch was not hard to describe and also relatively easy to model. Figure 11 illustrates the processes.

During the business hours customers enter the branch if they need to perform a transaction. They come into the counter hall that serves as waiting room and provides an overview over the counters availability. If all the counters are occupied, customers usually join the waiting line and wait until it is their turn. If a counter is or becomes available the customer steps in and asks the cashier for performing the intended transaction. When the service is finished, which might take a short or long time depending on the type of transaction, the customer steps back and leaves the branch.

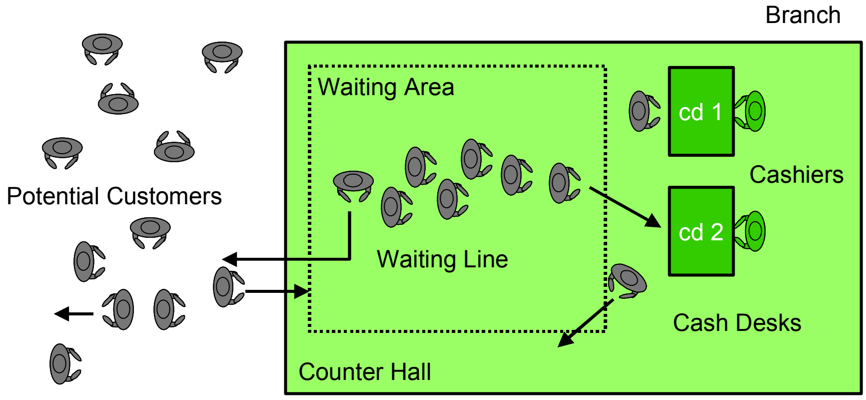

Figure 11: Business processes related to cash transactions in a bank's branch

Translating Figure 11 and the description given above in a system dynamics stock and flow diagram leads to Figure 12. The stock 'Potential customers of the branch' is initialised with the estimated amount of customers who want to come to a branch on a specific day for carrying out at least one cash transaction. This initial value is derived from one of the scenarios A to D described in section 3.

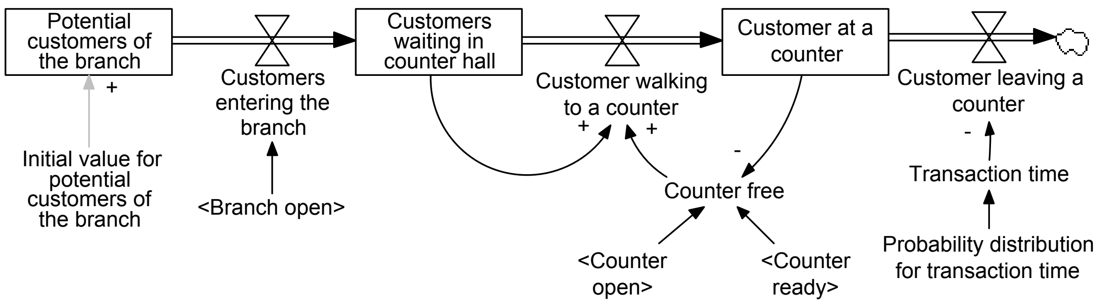

Figure 12: Stock and flow diagram of cash transaction processes in a bank's branch

The stock 'Potential customers of the branch' is decreased by an outflow – customers that enter the branch. Entries are modelled as a random variable, the distribution of which can be set by a lookup table. The project team decided though, that for all initial simulations of the four scenarios the distribution is assumed to be uniform. The reason for this simplification was that a tremendous amount of work would have to be carried out to determine the real distribution for each branch and workday individually. The branch manager however was offered the possibility to order new simulations by providing more realistic data if he was not satisfied with the assumption of a uniform distribution.

After having entered the branch, customers are waiting in the counter hall forming a queuing line until a counter becomes available for them. Therefore not an ordinary level but Vensim's QUEUE FIFO level was used in the model to represent the customers waiting in the counter hall (Vensim Reference Manual, 2000). The service process at the branch's counters has very discrete characteristics: only one customer can be served at one counter at the same time and the counter is occupied as long as the customer is being served. To model this structure adequately a subscript variable 'Counter' was introduced and subscripts were used for the variables 'Customers walking to a counter', 'Customers at a counter' and 'Customers leaving a counter'. Structurally this means that there is an array of flows draining the level 'Customers waiting in counter hall' and each flow is feeding a separate level representing the customers being served at the different counters (see Figure 13). Due to the discrete characteristic of the structure all the subscripted variables can have either the value 0 or 1.

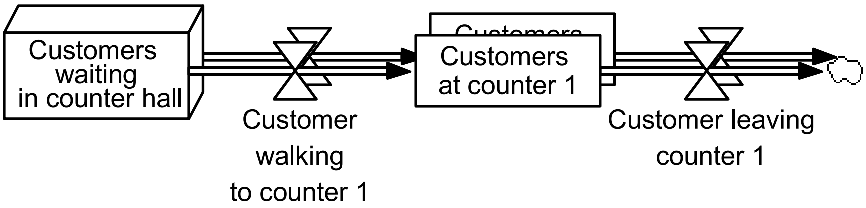

Figure 13: What subscripting means structurally

To allocate the counters available to the waiting customers, Vensim's ALLOCATE INTEGER function is used (Vensim Reference Manual, 2000). This function guarantees that exactly one customer is walking to a counter if it becomes available. How long a customer stays at a counter is determined by the transaction time. The customer is not leaving the counter until his transaction is finished. Due to the discrete perspective chosen the customers leaving a counter are modelled using Vensim's fixed delay function DELAY MATERIAL. Delay time is set equal to transaction time that may vary depending on the type of transaction and the group the customer belongs to. Therefore transaction time is again modelled as a random variable. As in the case of customers' entries the probability distribution of the transaction time can be set using a lookup table (Vensim Reference Manual, 2000).

To parameterise the model for some demo simulations the following data of a randomly selected Dresdner Bank's branch are used.

- Opening hours: 8.30AM to 12.30 PM and 2 PM to 5 PM
- Number of counters open: 2
- Equal priority for both counters (necessary for allocation)
- Initial values for potential customers of the branch: 137 for scenario A, 198 for scenario B, 222 for scenario C and 330 for scenario D. These values are computed from the scenario data of one day as shown in Table 2.
- A uniform distribution for the random variable 'Customers entering a branch'
- Scenario specific distributions for the random variable 'Transaction time' as shown in Figure 14.

Sc.	CG*	KKEZ	KKAZ	SPEZ	SPAZ	SPN	SOAK	SOVK	HGA	KSF	ZZW	SK	Σ 1	Σ 2
A	FI	11	3	1	0	0	0	0	1	1	9	0	26	
A	GE	10	4	1	0	0	0	0	1	1	8	0	25	
A	PK	15	28	5	12	14	3	3	1	1	4	0	86	137
B	FI	15	4	1	0	0	0	0	1	1	13	0	35	
B	GE	13	5	1	0	0	0	0	1	1	12	0	33	
B	PK	24	38	6	16	21	5	3	1	1	6	9	130	198
C	FI	16	5	1	0	0	0	0	1	1	15	0	39	
C	GE	15	6	1	0	0	0	0	1	1	16	0	40	
C	PK	27	48	6	18	17	5	3	1	1	8	9	143	222
D	FI	27	8	1	0	0	0	0	1	1	26	0	64	
D	GE	24	10	1	0	0	0	0	1	1	23	0	60	
D	PK	38	81	5	25	18	9	6	1	1	13	9	206	330

* customer group

Table 2: One day's transaction profile of a randomly selected branch

The probability distributions for the random variable 'Transaction time' shown in Figure 14 are the result of an aggregation process. The starting points of the aggregation are the distributions of transaction time for each customer group and transaction type. These 33 distributions (11 types of transaction and 3 customer groups) were estimated based on available data and the experience of cashiers. Figure 15 shows for example two curves for the transaction types KKEZ, ZZW, and SK for private customers. To get the weighted and aggregated curves shown in Figure 14, the numbers in the matrix of Table 2 have to be first expressed as percentages and then the resulting matrix has to be multiplied with the matrix lying behind Figure 15. Because the mixture of transaction in a branch varies from day to day, the distribution for the random variable transaction time is valid only for one single day and has therefore to be recomputed every day.

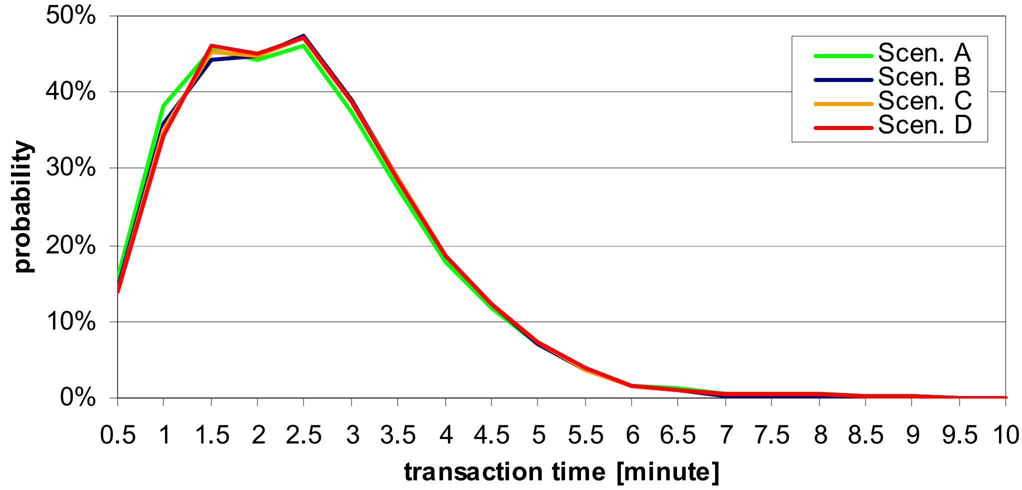

Figure 14: Scenario specific distributions for the variable 'Transaction time'

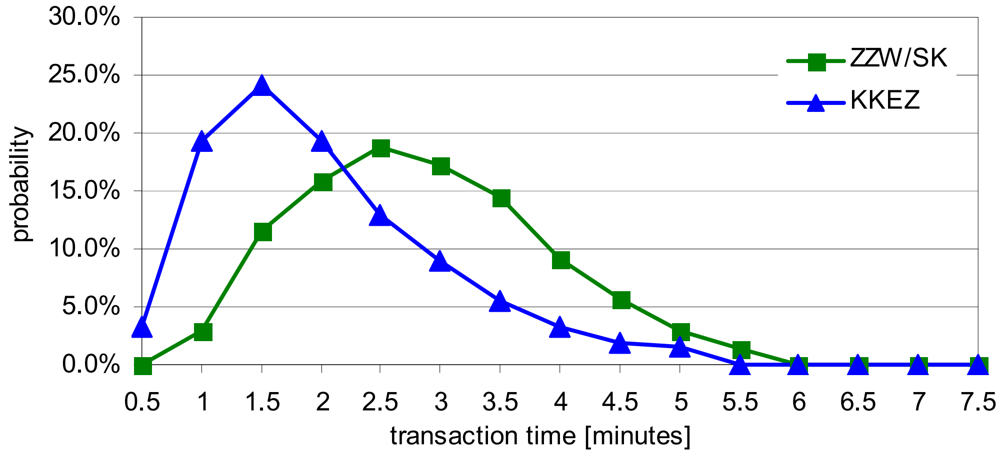

Figure 15: Probability distribution for two types of transaction (private customers)

The Figures 16 to 19 show the results of the simulation when the model is initialised with the parameters for scenario A and simulated once with one random sample for each of the two random variables.

As it should be customers are entering the branch pretty equally distributed over the opening hours (Figure 16).

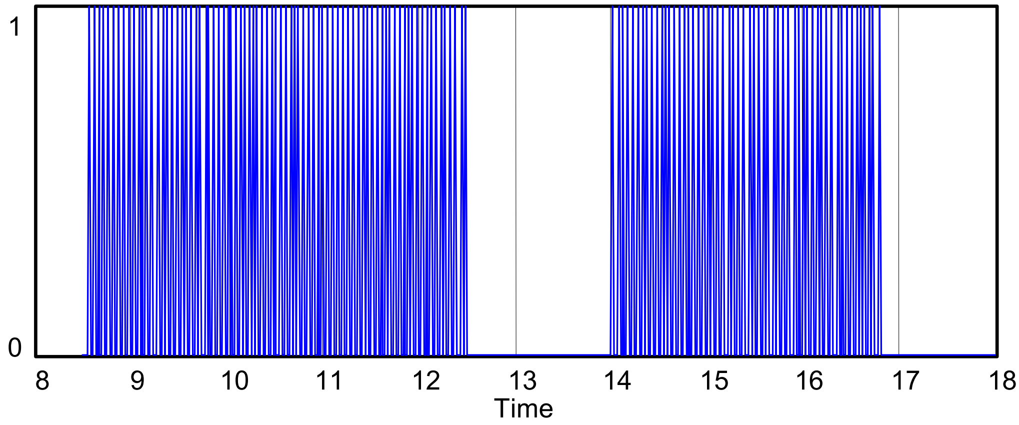

Figure 16: Customers entering the branch

Because the number of customers wanting to do transactions in the branch is relatively low, no bottleneck occurs. Figure 17 shows that at no point in time two or more customers have to wait in the branch simultaneously. All the customers entering the branch could be served immediately.

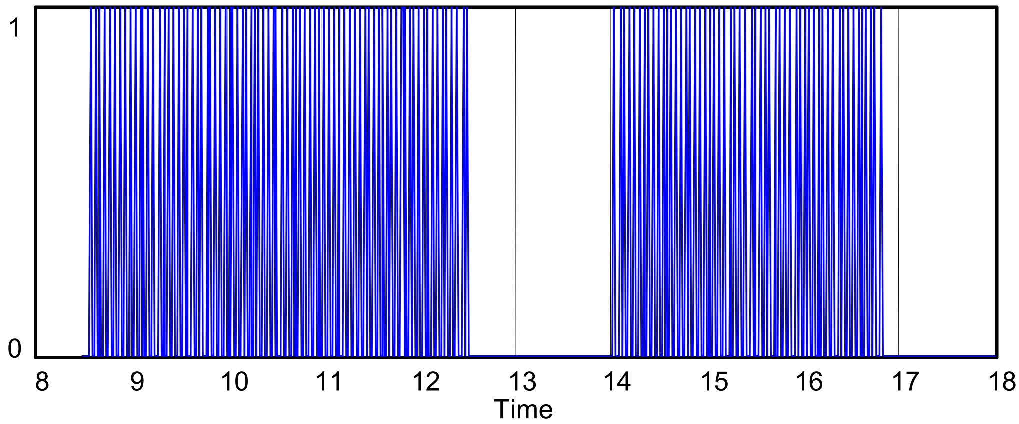

Figure 17: Customers waiting in counter hall

Figure 18 demonstrates that there are only very few situations during the day when the second counter is needed for serving customers. It is then not astonishing that the average service capacity of the two counters is used only up to about 50 % (Figure 19).

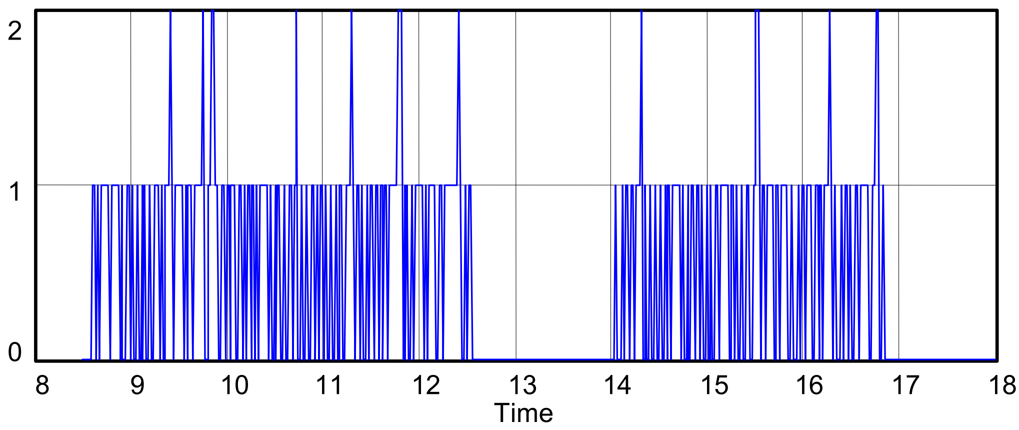

Figure 18: Customers being served

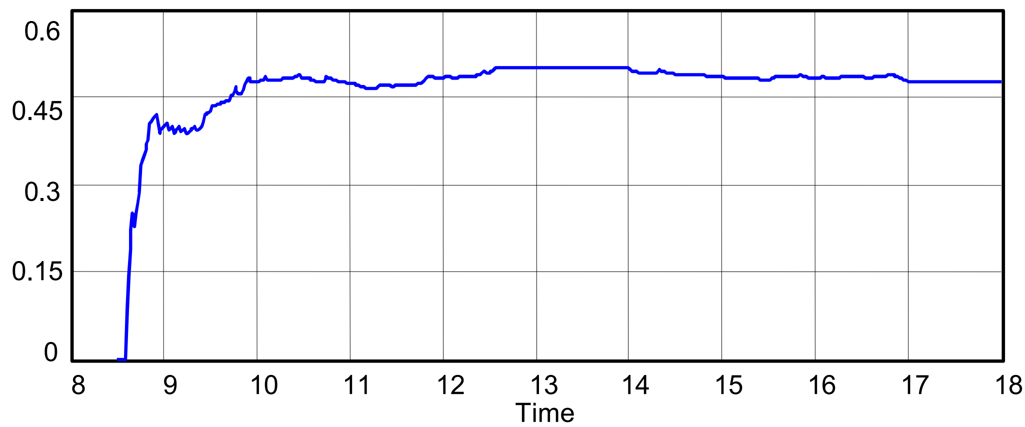

Figure 19: Average service capacity of counters used

To get an idea of the two random variables' impact on model behaviour, a sensitivity simulation is done. The only parameter changed is the random number seed variable that is needed to initialise the random number generator. Using 500 different random sequences as input for the variables 'Customers entering a branch' and 'Transaction time' the behaviour over time of the variable 'Average service capacity of counters used' varies as shown in Figure 20. The results came up to the project team's expectations.

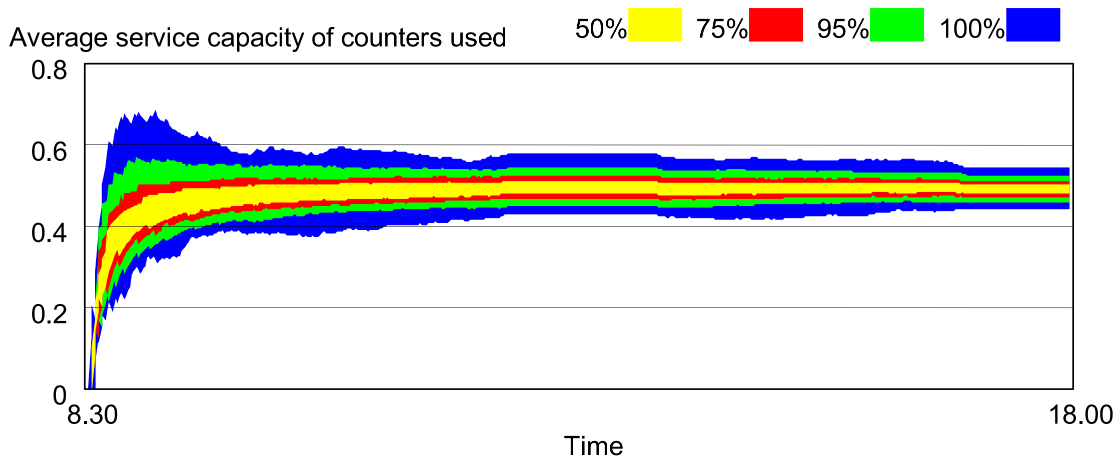

Figure 20: Sensitivity graph as illustration of the influence of the random variables[10]

But how will the branch's situation be when a bottleneck occurs? To answer this question the model is run with the parameter input for scenario D. Customers are now entering the branch in rapid succession, and very soon, huge queues develop. Figure 21 shows that by the time the branch is closing for lunch break, 50 customers are waiting in the counter hall. It takes the whole lunch break to serve them and to empty the branch. The situation during the afternoon is not much better. ¾ of an hour overtime has to be done to fulfil the customers' demand for cash transactions.

[10] The simulations results are displayed as confidence bounds. These are computed at each point in time by ordering and sampling all the simulation runs. Thus, for example, for a confidence bound of 50 % (yellow in Figure 20), 1/4 of the runs will have a value bigger than the top of the confidence bound and 1/4 will have a value lower than the bottom.

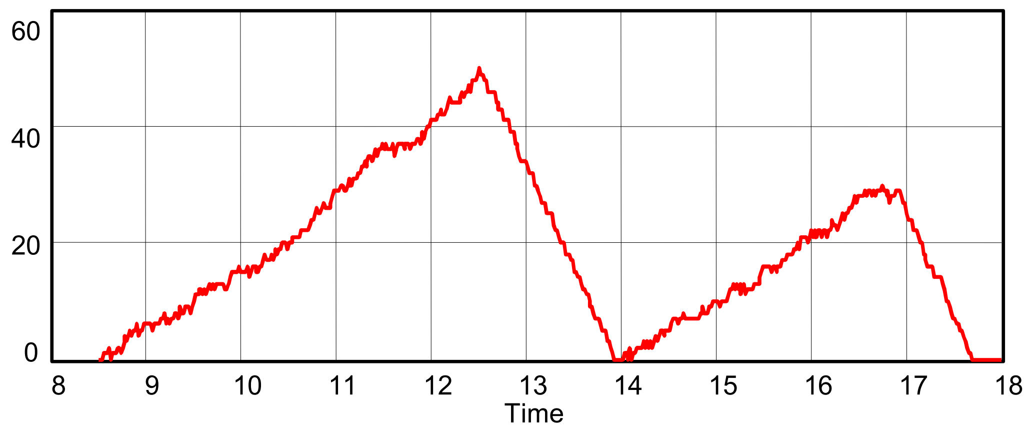

Figure 21: Customers waiting in counter hall in scenario D

One might argue that no customer will be willing to wait for almost 1½ hours to get some notes and coins changed. Therefore two further outflows from the level 'Customers waiting in counter hall' were added to the model (Figure 22). Some customers might be willing to come back to the branch sometime later that day. These customers flow back into the stock of potential customers of the branch. Others might not be willing to make once more an attempt to perform the desired transaction. Perhaps these customers will try to change their money some other day, or they may never come back again – for the one day's time horizon of the model, they flow beyond the boundaries of the model.

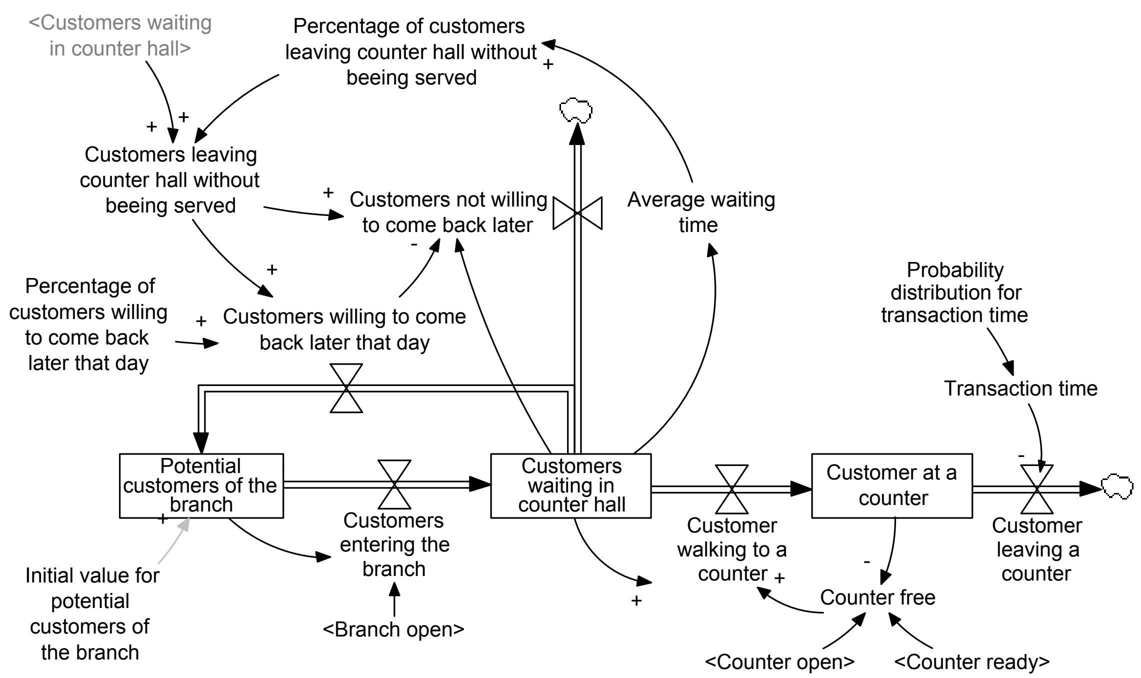

Figure 22: Stock and flow diagram of the enhanced queue simulation model

Due to the structural enhancement of the model, two more parameters had to be estimated: the percentage of customers willing to come back later that day and the customers' willingness to wait in counter hall. The values for both parameters were first estimated by the project team and then discussed again in a workshop with experts. As a result the percentage of customers willing to come back later that day was estimated to be ¼. And the curve shown in Figure 23 was accepted as input for the lookup table function relating the percentage of customers leaving the counter hall to the average perceived waiting time. In words Figure 23 means, that 95 % of the customers accept a waiting time of 2 minutes, 10 % of 5 minutes and so on. Everybody however would leave the branch, if the perceived waiting time was more than 14 minutes.

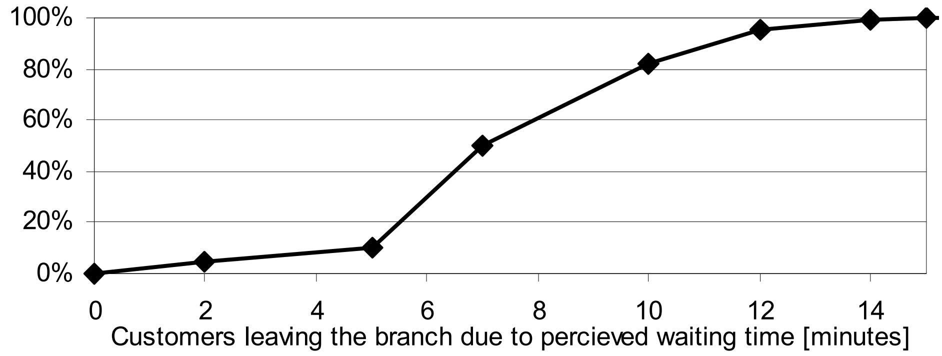

Figure 23: Customer's willingness to wait in a branch

The structural changes described above lead to a different behaviour of the model. As indicated by Figure 24 the queues are dramatically reduced. The reason however is not better service and more capacity, but customers leaving the counter hall because of long waiting lines. Due to this behaviour there is a tremendous difference in the number of customers served comparing the two model's outputs as shown in Figure 25.

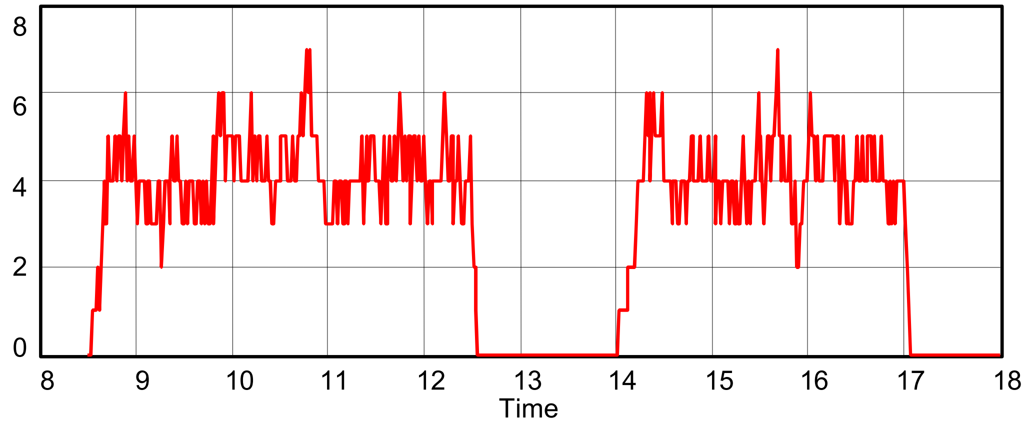

Figure 24: Customers waiting in counter hall in scenario D (enhanced model)

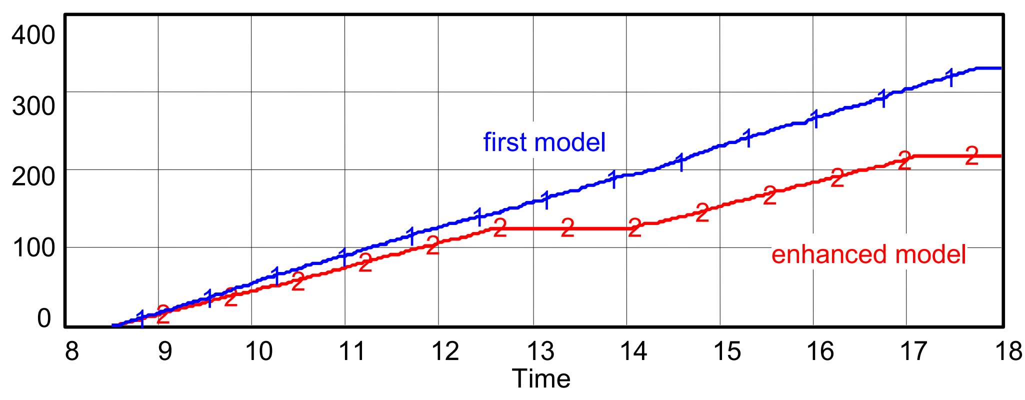

Figure 25: Comparison of the cumulated number of customers served in scenario D

The queuing simulation models were together with their assumptions, simplifications, and results presented and discussed several times during the project. Several validation tests were carried out (Sterman, 2000). Finally, everybody involved in the process was convinced that the structure as well as the behaviour of the models looked reasonable and appropriate to support the decisions outlined in section 2.

Because the model described above was suited to simulate one day of one Dresdner Bank branch, 50 simulations were necessary to cover the whole changeover period for one branch from 17th December 2001 to 28th February 2002. To gain one branch's results for all four scenarios A to D, 200 simulations had to be performed. All in all about 160,000 simulations had to be carried out to provide all the 800 Dresdner Bank branches with simulation based decision support information.

Each one of these 160,000 simulations had to be initialised with its own specific set of parameters stored in a large Microsoft Access database. To obtain direct access to this database and to manage this substantial amount of simulations, a user interface was programmed using Delphi and the model was rewritten in Object Pascal. The model was again validated and finally, around Easter 2001, the simulation program could start.

5 Simulation and Simulation Output

Because of the stochastic elements in the model, one simulation per day and per branch was not sufficient. A single simulation of a stochastic model is no more than a kind of behaviour snapshot based on only one sequence of random numbers (Pidd, 1998). Decisions that are taken based upon such a snapshot are pretty likely to be wrong. The reason why they are likely to be wrong is that no distinction is made between the effects of the sampling variation and those of the system configuration (Pidd, 1998). For more valid insights in the system's behaviour, the distribution of the output variables has to be determined and closely observed. To gain this information, a stochastic simulation model has to be simulated repeatedly – how often depends on the precision of the results wished (Steinhausen, 1994). Based on some tests and making a compromise between precision and simulation time, in this case 50 repetitions were considered necessary. Nevertheless, at least 8 million simulations were required to provide all the output data compulsory for decision support. Estimated simulation time on 800 MHz Pentium III computers was all in all about 800 hours. Using a computer pool of 15 machines, the simulations were done over two weekends.

To judge whether the situation in a specific Dresdner Bank's branch was critical or not, the project team decided to make the following information available:

- Cumulated transactions successfully performed
- Cumulated transactions that could not have been fulfilled
- Cumulated service minutes done
- Average waiting time per customer
- Maximum length of queue in counter hall

Using the information given above, a service index was additionally computed according to the following equation:

$$\text{service index} = \frac{\text{cumulated transactions performed}}{\text{cumulated transactions wanted by customers}}$$

So, the service index measures a branch's ability to serve its customers. Another interesting information could be derived, the counter capacity used. It could be computed as follows:

$$\text{counter capacity used} = \frac{\text{cumulated servide minutes done}}{\text{opening minutes * counters}} .$$

For each branch an eight pages report was designed showing the relevant parameters, the simulation results for all the scenarios A to D, and a quick overview over the branch's situation. This report was printed in a pdf document and distributed to the seven regional project teams in the middle of the year 2001. Members of these seven teams had the job to distribute the reports to the single branches and to discuss the simulation output and the measures that should be taken with them. To train the member of the regional project teams a regular project meeting and a workshop was used. Additionally a hot line was installed to provide support in the case of questions and the possibility to request for specific simulations based on different assumptions.

In addition to the branch-specific reports and more addressed to the euro 2002 project central office and the board of directors a rough clustering of Dresdner Bank branches was elaborated. Looking through the reports, three types of branches could be identified:

- Type 1 branches showed no bottlenecks even in scenario D. They were completely uncritical. The counter capacity used was permanently below 50 %, average waiting time per customer is low and the maximum queue length in the counter hall is short (Figure 26). Special cost-intensive measures for branches of type 1 therefore were regarded as unnecessary.

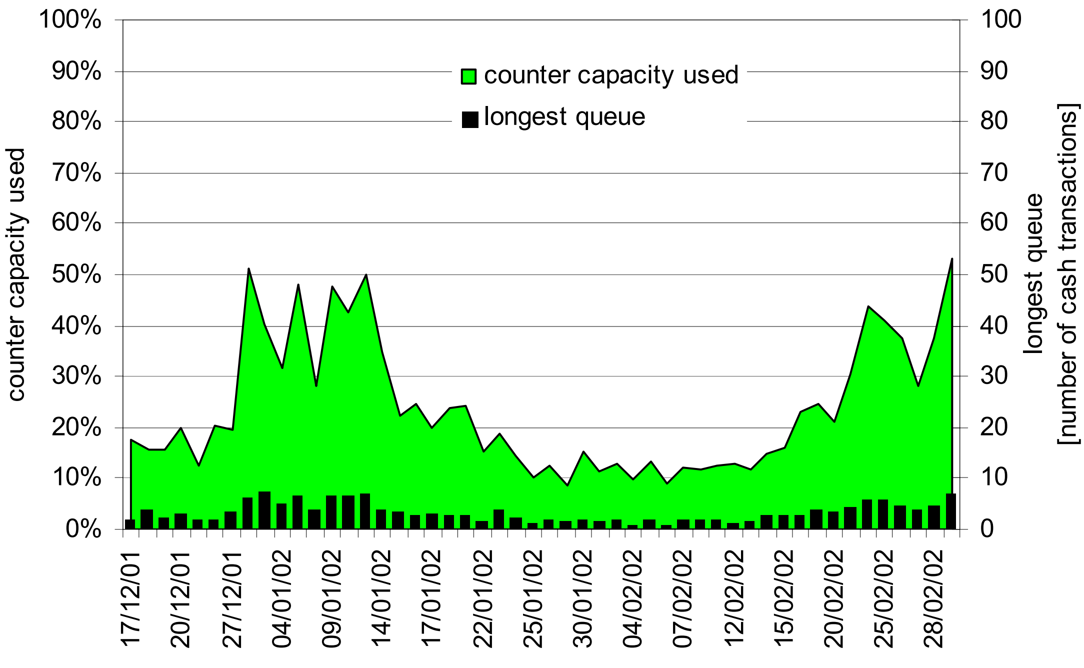

Figure 26: Type 1 branch (= uncritical)

- Branches of type 2 were faced with several days of great rush throughout the scenarios B to D. Especially at the beginning of January and at the end of February

2002 the counter capacity was highly used. The results were long queues and a lot of customers leaving the branches without being served (Figure 27). So, a combination of several, not too cost-intensive measures were thought to be sufficient for type 2 branches.

- Type 3 branches were facing severe difficulties during the period where euro coins and notes were put into circulation. Figure 28 shows that cashiers had almost no time for recovery throughout the whole changeover period. Overstrained employees were the rule. For this type of branch the euro introduction was feared to cause chaos. Therefore it was regarded as absolutely necessary to prepare an action plan to cope with the challenges.

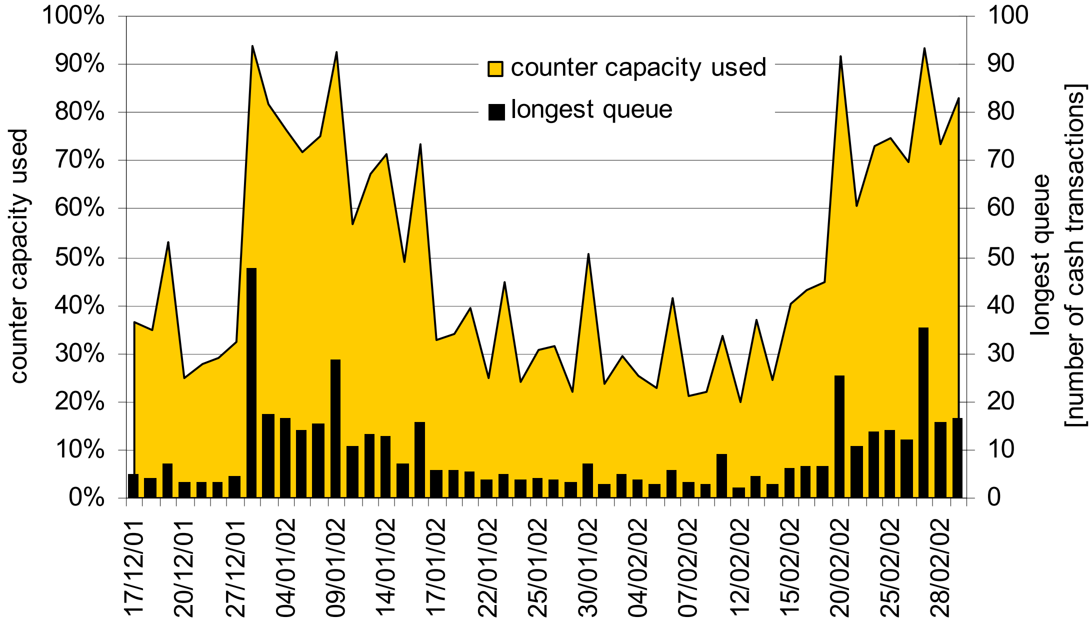

Figure 27: Type 2 branch (= some really critical days)

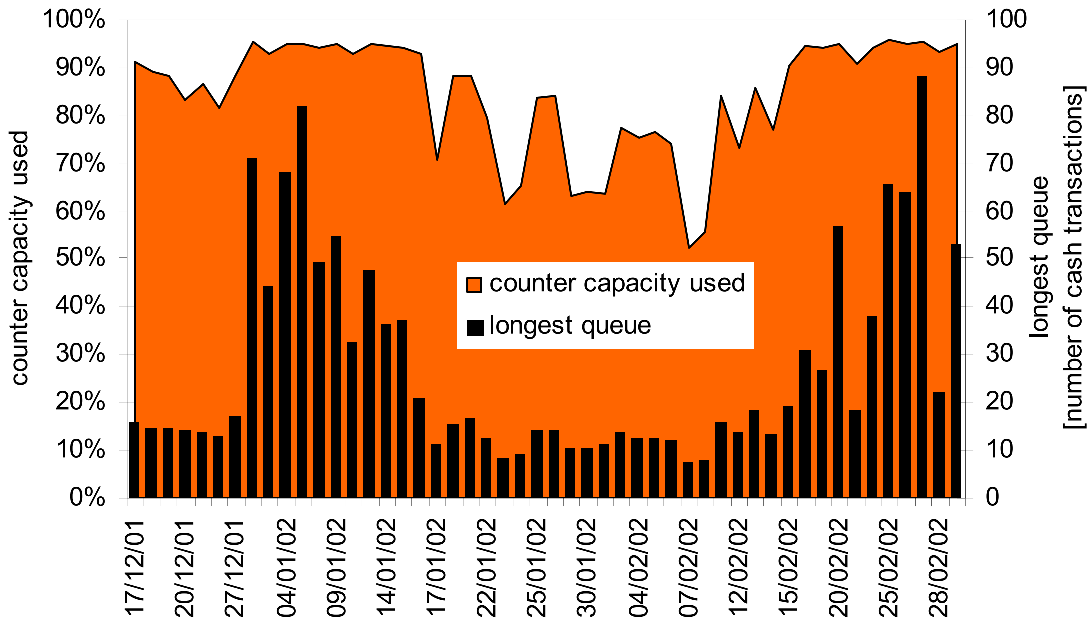

Figure 28: Type 3 branch (= very critical situation)

As a result of clustering, 95 of the 822 Dresdner Bank branches were identified as belonging to type 1 and were regarded as mostly uncritical. Only 32 branches were discovered as being highly critical i.e. that meant these branches had to expect more than 15 days with high workload. The overwhelming majority of branches – 695 exactly – were classified as type 2 branches. Therefore the simulation showed that the branches would have to deal with some critical days, but far from getting into severe troubles.

An even more detailed picture was the result of a further analysis and classification based on single days. In this analysis a workday in a branch was regarded as critical if the counter capacity used – based on the mean of all simulations – was greater or equal to 75 %. Workdays between 50 % and 75 % used capacity were categorized as medium-critical, and workdays below 50 % were seen as uncritical. Considering Dresdner Bank as a whole with 50 workdays between 17th December 2001 and 28th February 2002 and 822 branches, Figure 29 shows the result of the clustering efforts: scenario B for example is accompanied by 3.355 (or 8,2 %) critical days, 4.931 (or 12,0 %) medium-critical days and 32.814 (or 79,8 %) uncritical days.

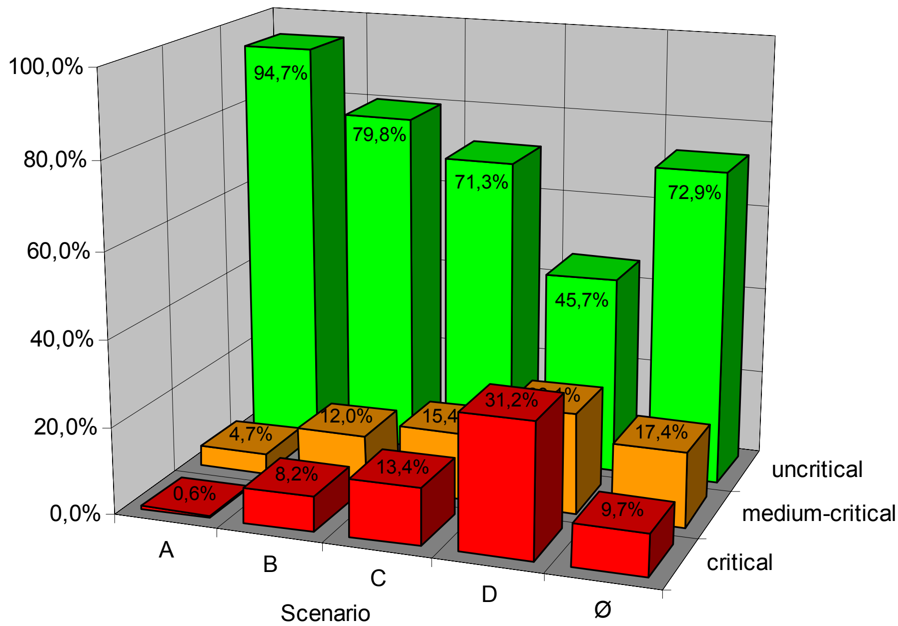

Figure 29: Clustering of workdays during changeover period

Simulation and analysis results showed that Dresdner Bank's branches were facing some challenges during changeover period. Absolute chaos on broad front was however pretty unlikely. An adequate mixture of measures put together for each branch individually could be sufficient for preventing severe troubles.

6 Conclusions

As stated in the very beginning, the changeover to the euro in Germany as a whole was a success story. The same is true for the Dresdner Bank. Although it was not completely possible to avoid queues – especially in the first days of 2002 – the exchange process went off smoothly. No severe technical problems occurred. Peter Timmerscheidt, member of Dresdner Bank's euro 2002 project team, pointed out: "I was very surprised that everything proceeded so fast, although the German people allegedly love their mark. The big pragmatism of the citizens was surprising for me too" (Dresdner Bank, 2002).

The simulation based branch reports have certainly not been the single crucial factor producing this success story. However, they have been valued as an important piece of a jigsaw by most of the members of the central and regional project teams involved in this subject. The development of scenarios of customer behaviour, the gathering of branch specific data and the simulation of the critical 50 days were seen as an important means for improved, fact-based discussions and argumentation.

References

Deutsche Bundesbank (Ed.): Gemeinsames Konzept für die Inverkehrgabe von Euro-Bargeld in der Bundesrepublik Deutschland, Frankfurt am Main: without publisher, 2001 (pdf document downloadable through http://www.bundesbank.de/euro/inhalt.htm, 18.07.2001).

Dresdner Bank (Ed.): Dresdner Banker, Issue 229, March, 2002.

European Commission: Communication from the European Commission to the European Council. Review of the introduction of euro notes and coins (6 March 2002), 2002, (pdf document downloadable through http://europa.eu.int/comm/economy_finance/publications/euro_related/2002/com0306_en.pdf).

Forrester, Jay W.: Industrial Dynamics, Cambridge: M.I.T Press, 1961.

Morecroft, John D.W.: Executive Knowledge, Models, And Learning, in: Morecroft, John/Sterman, John D.: Modeling for Learning Organizations, Portland: Productivity Press, 1994.

Pidd, Michael: Computer Simulation in Management Science, 4th ed., Chichester: Wiley, 1998.

Ringland, Gill: Scenario Planning: Managing for the Future, Chichester et al.: John Wiley & Sons, 1998

Steinhausen, Detlef: Simulationstechniken, München/Wien: Oldenburg, 1994.

Sterman, John D.: Business Dynamics: Systems Thinking and Modeling for a Complex World, Boston et al.: Irwin McGraw-Hill, 2000

Ventana Systems, Inc.: Vensim® Reference Manual, Harvard: without publisher, 2000

Appendix

For the base run displayed by Figure 5 (p. 9) the following parameter values were used:

Parameter	Value	Unit	Source
Available Transaction Capacity	120	[Minutes/Hour]	Maximum Value[11]
Average Transaction Time	1.95	[Minutes/Customer]	Data/Expert interv.
Number of a Branch's Customers	1780	[Customer]	Average value
Branch Workdays During the Dual Circulation Period	42	[Days]	Average value
Hours of Business per Day	8	[Hours/Day]	Average value
Number of Transactions in an Hour	0.25	[Transactions/Hour]	Estimation
Perception Delay	24	[Hours]	Estimation

Table 3: Base run parameter values

The probability of finding DM cash, the probability to receive DM instead of € as change and the curiosity were thought to be time dependent parameters. They were therefore modelled using lookup table functions. The parameters used for the base run were the results of an estimation process.

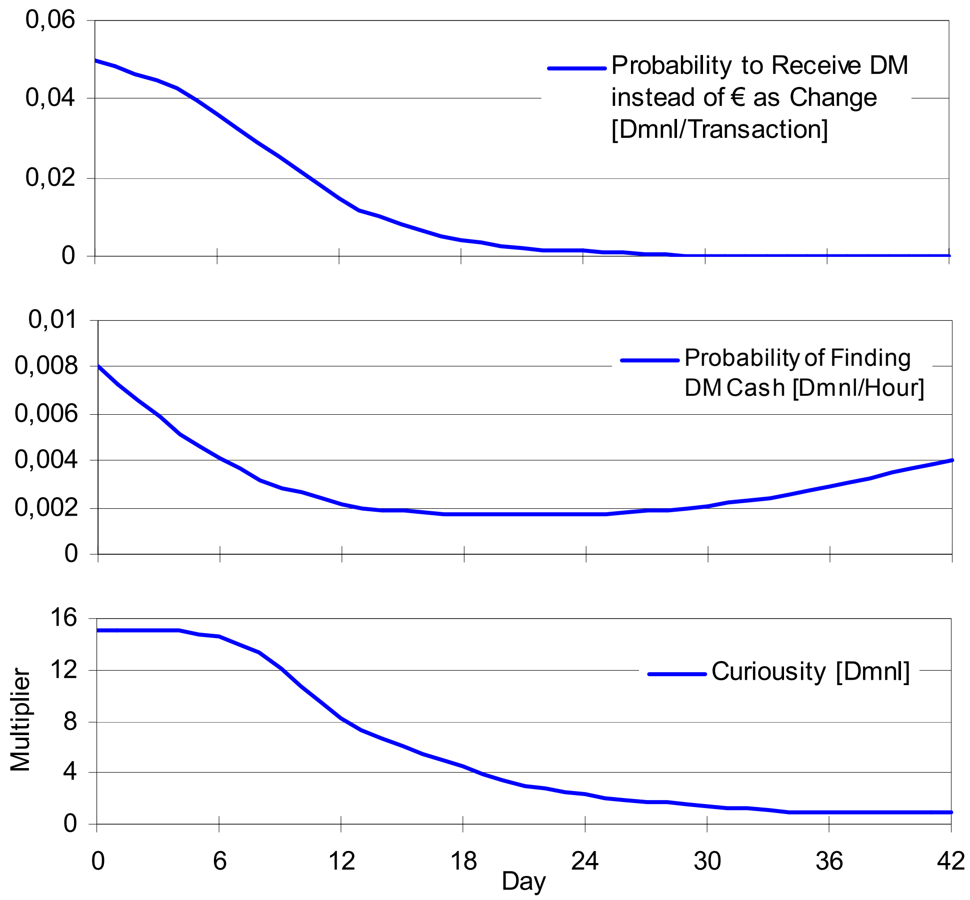

Figure 30: Base run values for the time dependent parameters

[11] A typical Dresdner Bank branch has two cash desks that can be used maximally 60 minutes per hour to service customers. The total available transaction capacity therefore is 120 minutes per hours assuming that the two cash desks are permanently staffed.

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