The Credit Card Model

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ABSTRACT

Credit cards are one of many ways through which people borrow money. With a credit card, a person can make purchases without using cash. The credit card company pays for the purchase, but the card user has to repay the money borrowed to the card company at a later time. In addition to the amount of the purchase, the card user also has to pay interest on the loan. Interest on a loan is calculated as a fixed fraction of the loan amount and is charged for the time period of the loan.

Interest payments reduce the amount of money the user of a credit card can spend on regular purchases. This paper presents a model that studies the way interest payments affect the quality of the credit card user's life by reducing the amount of money he can spend on other purchases.

The reader is assumed to have some system dynamics modeling experience, and should build the model along with the paper.

1. INTRODUCTION

In recent years, the use of credit cards and other forms of credit has increased tremendously. The increase in borrowing has, in many cases, led to personal financial problems such as personal bankruptcies and bad credit histories. Having a bad credit history makes it more difficult and expensive for a person to make a loan later. Credit problems arise because people borrow too much money without realizing the cost of borrowing. In addition to having to repay the loan, the borrower also has to pay interest on the loan. Interest is the cost of borrowing money and is calculated as a fixed fraction of the total loan amount. Interest payments reduce the amount of money the borrower can spend on other expenses.

A common use of credit is through the use of credit cards. Consider a young man named Joe Flogg who recently graduated from college and found a new job. Five months after he started the job, Joe applied for a credit card, which he received a month later. This paper studies the way Joe uses his credit card. Using a credit card affects the quality of his life. Joe follows some simple policies while using his credit card. He calculates how much he can spend on the card and how much money he will pay back to the credit card company according to his policies. His spending and repayment policies are described later in the paper.

The article in Appendix 9.1 describes some recent problems that have emerged because of the excessive use of credit cards. The problem being modeled is the effect of the overuse of credit cards on the quality of life of credit card users. The paper leads the reader through the process of converting a written description of the problem into a system dynamics model. It is recommended that the reader build the model while reading the paper. The reader should also read "Building a System Dynamics model Part 1: Conceptualization"[1] before continuing to read this paper.

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[1] Stephanie Albin, 1997. *Building a System Dynamics Model Part 1: Conceptualization* (D-4597), System Dynamics in Education Project, System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology, June 30, 36 pp.

2. USING A CREDIT CARD

Credit cards are issued by credit card companies. Joe's credit card, for example was issued by "International Express," a premier credit card company. When Joe makes a purchase using his credit card, International Express pays for his purchase. Thus, Joe owes International Express the amount of the purchase. The "Balance Payable" is the total amount of money Joe owes International Express. At the end of each month, International Express sends Joe a statement listing all purchases he charged to his card during the month and the "Balance Payable" from the previous month. The new "Balance Payable" is the sum of the new purchases charged this month, the "Balance Payable" from the previous month, and the interest charges on the previous month's "Balance Payable." Joe then pays a part or the entire amount of the new "Balance Payable." The unpaid part of the current "Balance Payable" and the interest on the unpaid part of the current "Balance Payable" will be added to next month's purchases to give next month's "Balance Payable." This model assumes that International Express starts charging interest on the amount of a purchase the moment Joe charges the purchase to his card. Read Appendix 9.2 to learn how credit card companies really charge interest on the "Balance Payable." As mentioned in the Introduction, interest is calculated as a fixed fraction, called "INTEREST RATE," of the "Balance Payable" for the time period that the "Balance Payable" is unpaid.

Joe uses his credit card for convenience, to avoid carrying large amounts of cash. When Joe does not have cash to pay for his purchases, he uses his credit card to pay for the purchases, planning to pay the credit card bill in the future. Therefore, to make the purchase, Joe is using money he does not have at the present time. He is taking a loan from International Express and will repay the loan at a later time. Therefore, he is using his future income today.

3. CONCEPTUALIZING THE USE OF A CREDIT CARD

The first step in building a model is identifying the problem to be analyzed. Appendix 9.1 describes some problems caused by the extensive use of credit cards by people. The purpose of this paper is to model and understand the reasons and the ways using a credit card can affect the quality of Joe Flogg's life. This model will address primarily two issues. The first issue is the amount of Joe's debt, that is, his "Balance Payable." The second issue is the effect of the use of the credit card on the quality of Joe's life. Joe uses his card mostly for small expenses, such as eating at restaurants and going to movies. All benefits from his credit purchases are enjoyed today, and no purchases have a long-term effect on Joe's life. Purchases with a long-term effect would include furniture, a computer, or anything that can be used for a long period of time. Hence, the quality of Joe's life is defined by his current spending ability, that is, the total amount of money he can spend at the present moment, and not by purchases made in previous time periods.

The next step is to determine the model boundary and identify key variables. The model boundary depends on the issues that the model studies. The model boundary is set by deciding whether or not a certain variable is important in determining the system's behavior. The model boundary can be determined while studying the variables that affect the system.

The debt accumulated because of the use of the credit card is the amount Joe has to pay to International Express. The debt is called "Balance Payable." "Balance Payable" is a stock because it is the accumulation of all the money Joe has borrowed from International Express, plus the interest charged on the borrowed money, less the money he has paid back to International Express. "Balance Payable" increases when Joe charges a purchase to his credit card because Joe is borrowing more money from International Express. The flow of purchases charged to the credit card is called "credit card purchases." The interest charged on "Balance Payable" also increases the "Balance Payable." The inflow of interest is called "interest charges." "Balance Payable" is reduced by "payments" Joe makes to International Express. The "payments" reduce the amount of money Joe owes to International Express. The stock of "Balance Payable" and the flows into and out of the stock are shown in Figure 1. Figure 1 forms the core of the model.

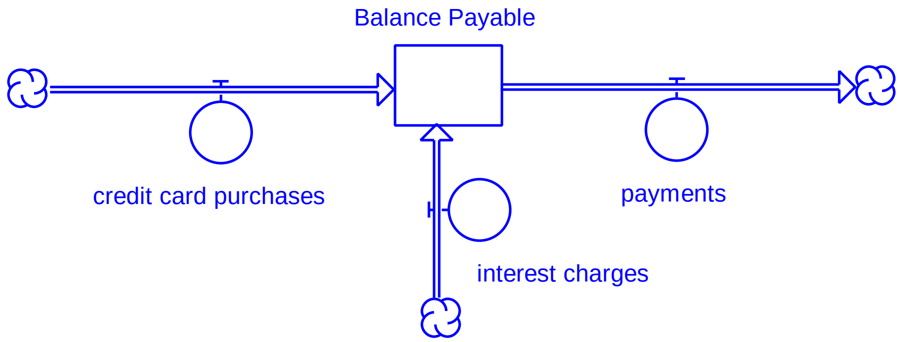

Figure 1: The stock and flows in the credit card system

Discussing the system and studying the stock and flows helps to identify other important variables in the system.

To spend any money at all, Joe must have a source of income. The source of income for most people is their weekly or monthly paycheck. Joe's paycheck is the amount of money he receives each month for the work he does at his job. Assume that Joe's paycheck is constant over the time period that the system is studied. Therefore, the model contains a constant called "PAYCHECK." Over a period of a few years, inflation will reduce the real buying power of Joe's paycheck amount. However, the effect of the inflation rate[2] is very small in the time period considered and is not important in the model in this paper. Thus, the inflation rate is outside the model boundary. This model also assumes that Joe's pay does not increase, and that he does not receive any bonuses.

The amount of money Joe can borrow on his credit card is limited. The maximum amount of money Joe can borrow is called the "CREDIT LIMIT." International Express limits the amount Joe can borrow so that he does not overcharge on his credit card. Because Joe's income is fixed, he may be unable to repay his debts if he borrows too much money. The "CREDIT LIMIT" also helps International Express limit losses in case Joe defaults, that is, if Joe does not repay the debt. If Joe defaults, the maximum amount of money International Express can lose is the "CREDIT LIMIT." For Joe, the "CREDIT LIMIT" is constant.

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[2] "Inflation rate" is the rate of increase of price levels in a certain region, usually measured for a country. Price levels in an economy are measured by the Consumer Price Index (CPI). Hence, the inflation rate is the rate of change of the CPI.

Different people have different spending habits and different ways of paying their bills. The spending and repayment policies people use can be formulated in many ways.

Joe has two sources of money to spend: the “PAYCHECK” and the credit available on his credit card. Joe’s expenses include purchases, which determine the quality of his life, and “payments” to International Express. The “available credit” at any time is the maximum amount Joe can spend on his credit card at that time. The “available credit” is the difference between the maximum balance allowed, the “CREDIT LIMIT,” and the current “Balance Payable.” Joe spends a fixed fraction of the “available credit,” called “SPENDING FRACTION,” each month.

Each month, International Express sends Joe a statement, showing the “Balance Payable” and his credit purchases for that month. Joe does not, however, have to pay the entire balance each month. He is required to make a certain minimum payment, and the unpaid amount can be paid later. Joe has to pay an amount equal to or less than the “Balance Payable,” but more than or equal to the required minimum payment. Because the “interest charges” are the expense on the debt, Joe pays only the “interest charges” each month. Therefore, “payments” equal “interest charges.”

The model also studies the quality of Joe’s life. The “quality of life” has been defined as the total value of purchases Joe can make at any time. The total value of the purchases equals the sum of the amount Joe charges to his credit card, the “credit card purchases” and the amount of his “PAYCHECK” he spends on “cash purchases.” “Cash purchases” equal the amount left from the “PAYCHECK” after making the “payments.” Joe cannot spend the entire “PAYCHECK” on “cash purchases,” except when the “payments” are zero. “Payments” are zero only when the “Balance Payable” is equal to zero, that is, when Joe is not using the credit card.

4. Formulation of the Model

Section 4 describes the system and the variables. The equations of the variables must be formulated from the written description. The reader should understand the process of converting the words into mathematical terms. The italicized words in this paper are helpful in finding the relationships between variables. For example, ë*of*' implies multiplication, ë*per*' means division, and ë*sum of*' means addition. The descriptions also help to find the units of the variables. '*Amount of money*' is measured in dollars and '*amount spent each month*' is in dollars per month.

The only stock in the system is the "Balance Payable." "Balance Payable" is the *amount of money* Joe owes to International Express. "Balance Payable" is increased by "credit card purchases" and "interest charges" and reduced by "payments" made to International Express.

Balance_Payable(t) = Balance_Payable(t - dt) + (credit_card_purchases + interest_charges - payments) * dt

INITIAL VALUE = 0

DOCUMENT: The "Balance Payable" is the amount of money Joe owes to International Express.

UNITS: Dollars

4.1 Inflow to "Balance Payable": "credit card purchases"

The "credit card purchases" are the purchases Joe makes on his credit card each month. The "credit card purchases" flow is a fixed fraction, the "SPENDING FRACTION," *of* the "available credit." The "available credit" is the maximum amount of money Joe can charge on his card and is equal to the *difference* between the "CREDIT LIMIT" and the "Balance Payable." Therefore, two factors affect the "credit card purchases" flow: the "available credit" and the "SPENDING FRACTION." The "available credit" is also affected by two factors: the "CREDIT LIMIT" and the "Balance Payable." Therefore, the systems diagram looks like Figure 2.

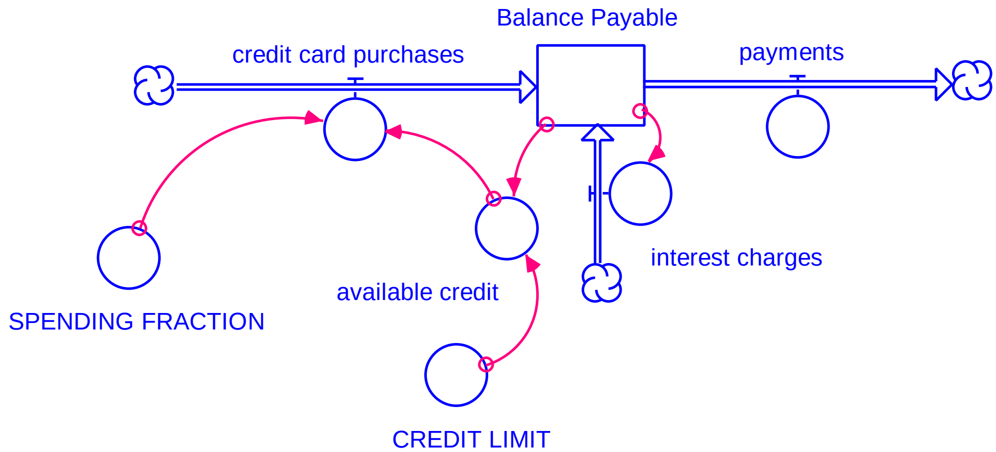

Figure 2: Inflow of "credit card purchases"

The "credit card purchases" represent the *amount of credit purchases made each month.* "Credit card purchases" is a fraction, the "SPENDING FRACTION," *of* the "available credit."

credit card purchases = SPENDING FRACTION * available credit

DOCUMENT: "Credit card purchases" is the amount Joe charges on his credit card each month, and is a fixed fraction, the "SPENDING FRACTION" of the "available credit."

UNITS: Dollars / Month

The "SPENDING FRACTION" is the fraction *of* the "available credit" Joe spends on "credit card purchases" each month. The "SPENDING FRACTION" is constant and can have any value between zero and one. A value of zero means that Joe never uses his credit card because he is not making any "credit card purchases." A value of one means that Joe spends all the "available credit" in the first month. Assume Joe spends ten percent, or 0.1 *of* the "available credit" *each month*.

SPENDING FRACTION = 0.1

DOCUMENT: The "SPENDING FRACTION" is the fraction of the "available credit" Joe spends on "credit card purchases" each month.

UNITS: 1 / Month

The "available credit" is the maximum *amount* Joe can spend on his credit card at any given time. The "available credit" is the *difference* between the maximum amount Joe is allowed to borrow, the "CREDIT LIMIT," and the "Balance Payable." The definition gives the following equation:

available credit = CREDIT LIMIT - Balance Payable
DOCUMENT: "Available credit" is the difference between the "CREDIT LIMIT" and "Balance Payable." The "available credit" is the maximum amount of money Joe can charge to his credit card at the time.
UNITS: Dollars

The "CREDIT LIMIT" is the maximum *amount* Joe can accumulate on his credit card. The "CREDIT LIMIT" is constant and is the maximum value the "Balance Payable" can have. Let Joe have a credit limit of $6000. Let time zero be the time when Joe started his job. Joe received his credit card six months after he started his new job. Thus, "CREDIT LIMIT" is zero for the first six months, and $6000 after six months. A STEP function can be used to model the "CREDIT LIMIT."[3]

CREDIT LIMIT = STEP (6000, 6)
DOCUMENT: The maximum amount Joe can charge on his credit card. It is the maximum value of the "Balance Payable."
UNITS: Dollars

4.2 Inflow to "Balance Payable": "interest charges"

Another inflow to the "Balance Payable" stock is the flow of "interest charges." As defined earlier, the "interest charges" on credit are computed as a fixed fraction, the

[3] The amount of the "CREDIT LIMIT" ($6000) and the time when Joe gets the credit card (six months) can be introduced as two separate constants. The "CREDT LIMIT" can then be modeled as a step function of the two constants instead of just the numbers. Introducing the constants makes changing the values of the constants more convenient.

"INTEREST RATE," *of* the "Balance Payable." The two factors affecting "interest charges" are the "INTEREST RATE" and the "Balance Payable," as shown in Figure 3.

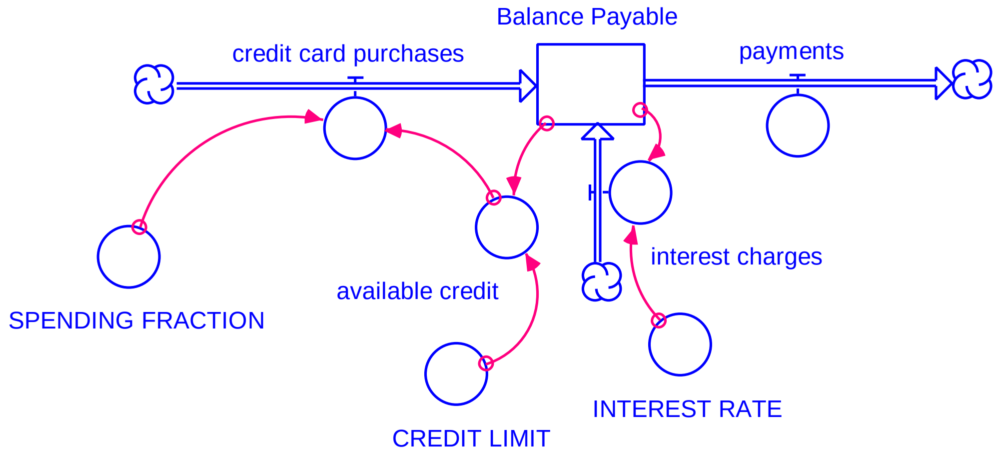

Figure 3: Inflow of "interest charges"

The "interest charges" are a fraction, the "INTEREST RATE," *of* the "Balance Payable." "Interest charges" are the *amount of money charged each month* on the loan.

interest charges = INTEREST RATE * Balance Payable

DOCUMENT: "interest charges" is the interest charged each month on the "Balance Payable."

UNITS: Dollars / Month

The "INTEREST RATE" is *constant*. International Express charges interest at 18% *per year*, or approximately 1.5% *per month.*[4]

INTEREST RATE = 0.015

DOCUMENT: The fraction of the "Balance Payable" charged as interest per month.

UNITS: 1 / Month

4.3 Outflow from "Balance Payable": "payments"

The only outflow from "Balance Payable" is the flow of "payments" made to International Express.

Joe pays only the "interest charges" on the "Balance Payable." Thus, the "payments" outflow is exactly equal to the inflow of "interest charges." Therefore, "payments" can be modeled as in Figure 4.

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[4] Eighteen percent interest each year should equal 18? 12 = 1.5% per month. However, because interest is compounded, the monthly interest rate will be less than 1.5%. Read Appendix 9.3 to understand how interest on a credit card balance is calculated.

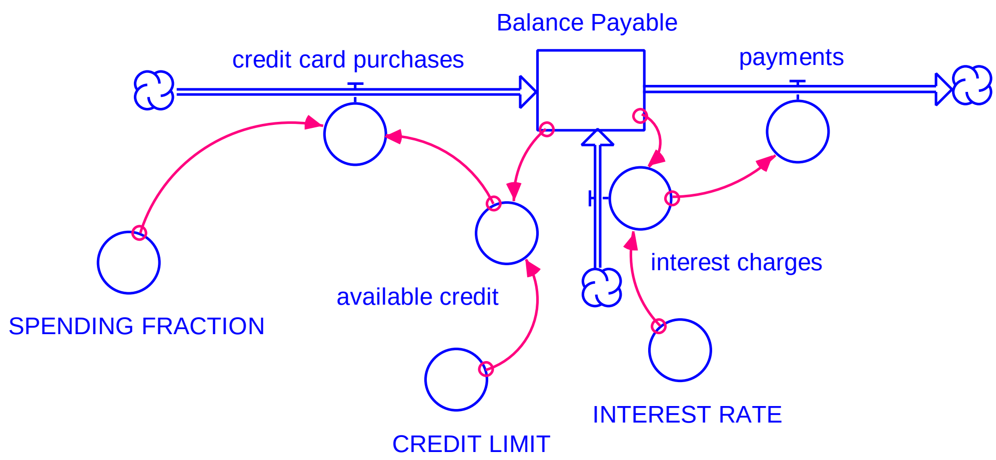

Figure 4: Outflow of “payments”

payments = interest charges

DOCUMENT: The “payments” is the money Joe pays to International Express.

UNITS: Dollars / Month

Flows cannot, however, be measured instantaneously. It is incorrect to set a flow equal to another flow. A new variable called “interest on balance,” which is equal to the “interest charges,” can be introduced. Thus, “interest charges” and “payments” both equal “interest on balance.” The model changes as shown in Figure 5.

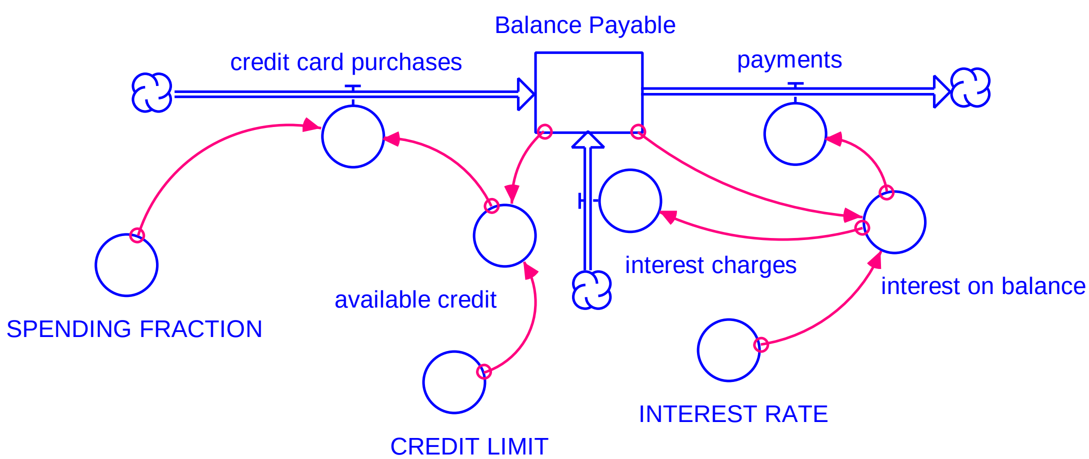

Figure 5: interest on balance

interest on balance = Balance Payable * INTEREST RATE

DOCUMENT: The interest charged on Joe's "Balance Payable" by International Express.

UNITS: dollars / Month

The equations for "interest charges" and "payments" also change to:

interest charges = interest on balance

payments = interest on balance

Introducing the variable "interest on balance" eliminates the problem of setting two flows equal to each other in the model. In principle, rates cannot control other rates. As shown, each rate comes from the same level and constant. Good modeling practice dictates that if easily avoidable, two flows should not be set equal to one another.

4.4 Other variables

Joe pays his credit card bills with money from his "PAYCHECK." By assumption, Joe spends the money remaining after paying the credit card bill on purchases. Purchases made with money from his "PAYCHECK" are called "cash purchases."

The "PAYCHECK," the amount Joe earns each month, is *constant*. The model does not consider raises in salary over time. At his present job, Joe earns $2000 *per month*.

PAYCHECK = 2000

DOCUMENT: The "PAYCHECK" is the amount of money Joe earns each month.

UNITS: Dollars / Month

The "cash purchases" equal the *amount left from* the "PAYCHECK" after paying the "interest charges," that is, after making the "payments." Because the "payments" are equal to the "interest on balance," "cash purchases," as shown in Figure 6, is the *difference* between the "PAYCHECK" and "interest on balance."

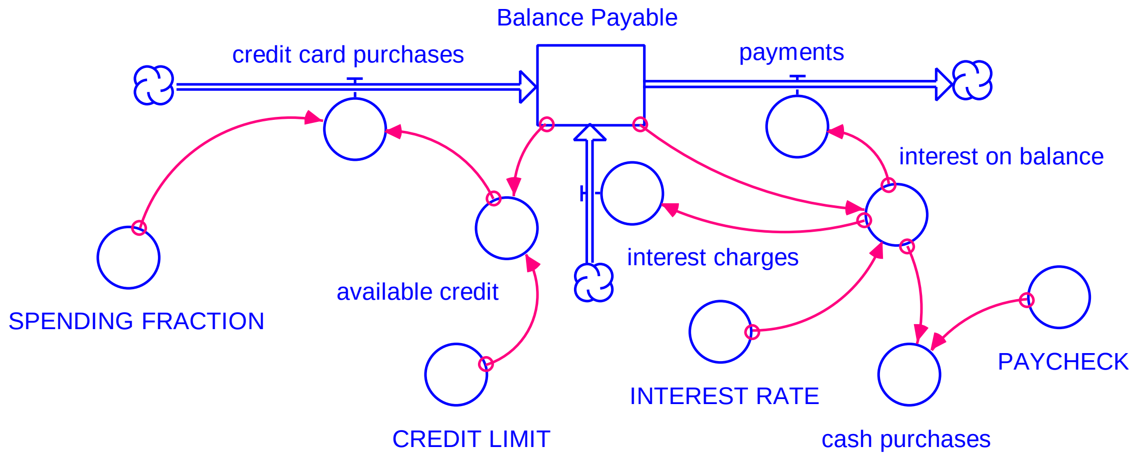

Figure 6: "cash purchases"

cash purchases = PAYCHECK - interest on balance

DOCUMENT: The purchases made each month with the money left from the "PAYCHECK" after making the "payments."

UNITS: Dollars / Month

By definition, the quality of Joe's life at any time is the total amount of money he can spend at that time. Joe can make cash purchases and credit purchases; hence, Joe's "quality of life," as shown in Figure 7 is the *sum* of "cash purchases" and "credit card purchases."

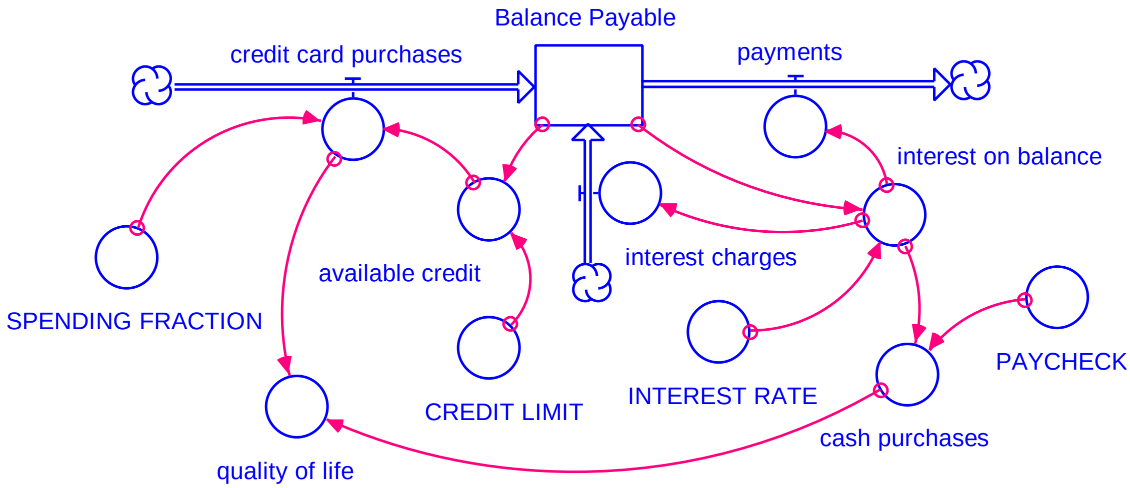

Figure 7: Model of the credit card system

quality of life = cash purchases + credit card purchases

DOCUMENT: The "quality of life" is the total amount of money Joe can spend at any time.

UNITS: Dollars / Month

The stock, flows, constants, and variables in the system have been modeled. Figure 7 shows the complete model of the system. The reader should not simulate the model yet.

The model is now complete but has not been edited. Editing is the process of deleting any part of the model that is not important in the system. Be sure to save the model in Figure 7 before making any changes.

5. EDITING THE MODEL

After building the model of the entire system, it is important to edit the model. Often, parts of the system are repeated, insignificant, or can be modeled in an easier way. Editing the model makes the model concise by simplification and more useful by removing insignificant parts.

In Figure 7, the “interest charges” inflow and the “payments” outflow are equal. Therefore, the “interest charges” inflow and “payments” outflow change the “Balance Payable” by equal amounts but in opposite directions. Thus, the combined effect of “interest charges” and “payments” on the “Balance Payable” is zero. Therefore, both “interest charges” and “payments” flows can be deleted to simplify the model. Deleting the flows should not affect the behavior of the model.

Editing a model may affect the equations of variables in a model. In Figure 7, only the “Balance Payable” is directly affected by the “payments” and “interest charges” flows.

The equation for the “Balance Payable” becomes:

Balance_Payable(t) = Balance_Payable(t - dt) + (credit_card_purchases) * dt
INIT Balance_Payable = 0

The final, edited model of Joe using a credit card is shown in Figure 8:

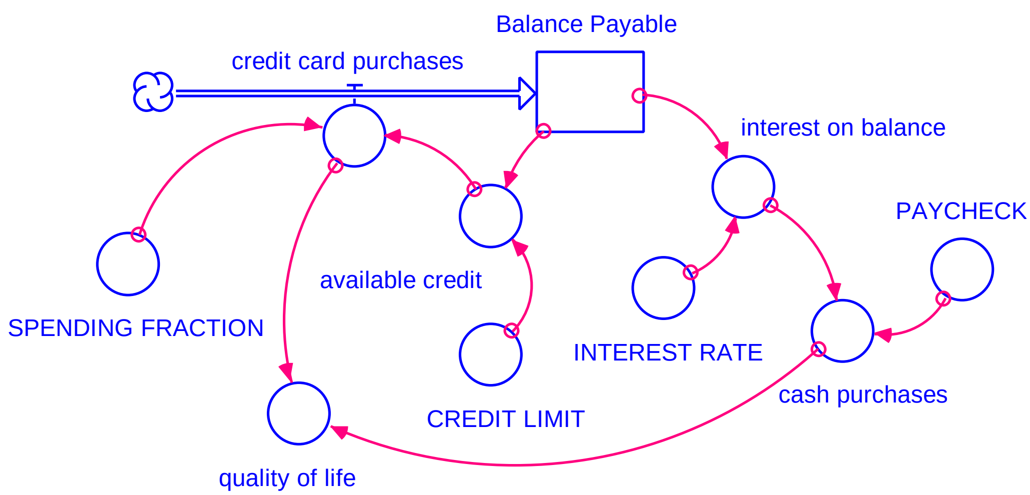

Figure 8: deleting “interest charges” and “payments”

Because “interest on balance” represents the interest charged on the “Balance Payable,” the interest charges can be studied directly by observing the behavior of “interest on balance” over time.

After deleting the flows of “interest charges” and “payments” and changing the equation of “Balance Payable,” the model looks like Figure 8. Save the model in Figure 8 as a new file. The model in Figure 7 will be required later. The documented equations for the model in Figure 8 are in the Appendix 9.3. Do not run the model yet.

The behavior of the model in Figure 8 should be the same as the behavior of the model in Figure 7. The only way to make sure that the behavior of the model has not been changed by the editing is to compare the behavior of the variables over time. Do not run the models at this time. Some questions about the models have to be answered first.

6. EVALUATING THE MODEL

The key variables in the model are “Balance Payable,” “quality of life,” and “interest payments.” Read the equations for the variables and look at the feedback loops that affect them. Try to estimate the behavior of the variables and plot the expected behavior over time. Appendix 9.4 explains the process of mentally simulating the model to estimate the behavior of the system.

Now run both the model in Figure 7 and the edited model in Figure 8 over a time horizon of 72 months. A period of 72 months is probably a long enough time period to observe the long-term dynamics of the system. Change the time period and rerun the models to observe the behavior of the models over different time intervals. Compare the behavior of the models to make sure they demonstrate the same behavior. Clearly, editing the model did not change the behavior of the variables.

Analyzing a model gives insight to the feedback loops that drive the behavior of the system. Understanding the system’s behavior makes it possible to formulate policies to improve the performance of the system.

The main purpose of the model is to study the quality of Joe's life, represented by the variable "quality of life." Look at the graph for "quality of life" and "PAYCHECK," shown in Figure 9.

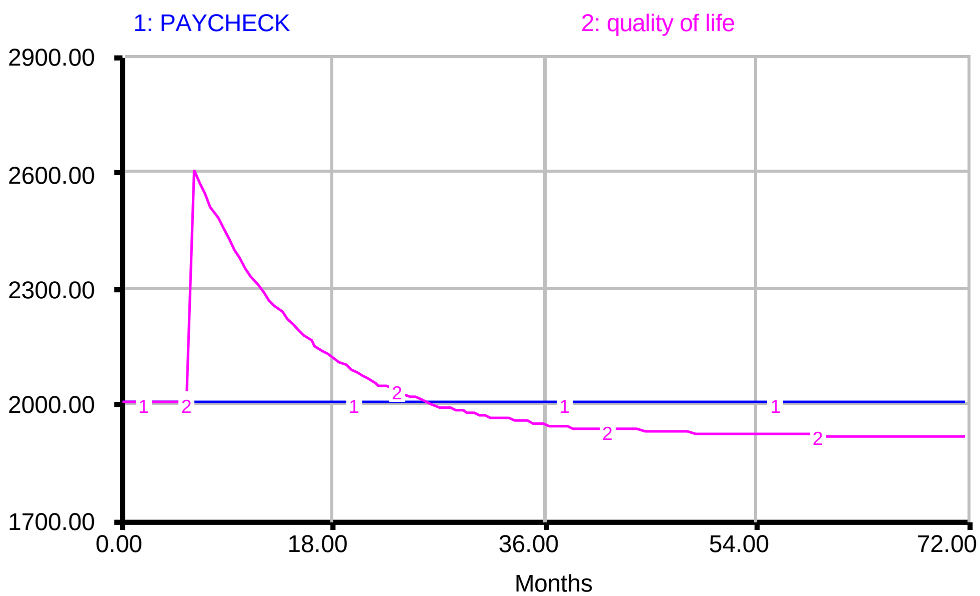

Figure 9: Behavior of "quality of life"

The quality of Joe's life equals his "PAYCHECK" when he does not have a credit card. When Joe does not use a credit card, he does not have to pay any interest because he owes no money to any credit card company. Therefore, Joe can spend his entire "PAYCHECK" on "cash purchases," and "quality of life" is equal to the "PAYCHECK."

The graph in Figure 9, therefore, shows the quality of Joe's life under two situations. The "PAYCHECK" curve shows the quality of Joe's life if Joe never uses a credit card. The "quality of life" curve shows the quality of Joe's life when he uses a credit card.

The "quality of life" is constant and equal to the "PAYCHECK" until Joe receives the credit card. Immediately after receiving the card, Joe's "quality of life" increases sharply. Joe now has a large amount of "available credit" to spend in addition to the "PAYCHECK." When he uses his credit card to make purchases, his "quality of life" increases because he can spend more than his "PAYCHECK." As Joe makes more "credit card purchases," his "Balance Payable" increases. Therefore, the "available credit" decreases, and so do the "credit card purchases." The behavior of "credit card purchases" is driven by a negative feedback loop. As the "credit card purchases" decrease, Joe's "quality of life" also decreases. When Joe has spent an amount equal to the "CREDIT LIMIT," he cannot charge any more purchases to his credit card. Joe's "quality of life" is now equal to his "cash purchases." The "cash purchases" have an equilibrium value of about $1910 per month, as can be seen from a graph or table of the "quality of life." The equilibrium value of "cash purchases" can also be calculated by setting "credit card purchases" equal to zero and solving the equations for the variables to get the equilibrium values of "interest on balance," "cash purchases," "credit card purchases," and "quality of life." The "interest on balance" is $90 per month. The equilibrium value of "quality of life," $1910 per month, is lower than the value of the "PAYCHECK."

7. CONCLUSION

The quality of Joe's life rises when he starts using his new credit card. Over the next few months, however, the quality of his life gradually declines and reaches an equilibrium value. The equilibrium value is lower than the quality of Joe's life before he started using the credit card. The quality of Joe's life stays lower than the "PAYCHECK" as long as he follows his current policy of paying only the interest charges on the "Balance Payable." Therefore, using the credit card improves the quality of Joe's life for a short period of time, but reduces the quality of his life for a long period.

Joe also has a huge debt, the "Balance Payable," that he will have to repay to International Express. To repay the loan, Joe's payments will have to be larger than the "interest on balance," so his "cash purchases" will decline further. Therefore, repaying the loan will further reduce the quality of Joe's life.

The model presented in this paper is a classic example of the "short-term benefit, long-term cost" behavior of complex systems. Borrowing on credit cards allows an immediate increase in Joe's "quality of life" for a short period of time. The consequence in the longer term is a lower quality of life while repaying the loan and interest.

The system presented in this paper shows that a short-term benefit can prove to be expensive in the long-term. The trade-off in short-term and long-term results occurs not only in the system of Joe using his credit card, but in many other systems. Often, policies generate excellent results quickly, but if implemented for a long time, they prove to be detrimental. The opposite is also true. Most strategies which are beneficial in the long-term usually have negative effects in the short-term. Before taking actions or implementing a policy, the long-term effects of the policy should be considered.

8. APPENDIX

8.1 Credit Card Problems

An article in the September 25, 1996 issue of *The Wall Street Journal* carried an article titled “Banks’ Marketing Blitz Yields Rash of Defaults.”[5] The article describes the effect of the increased use of credit cards on the lives of many credit card users.

In 1995, credit card companies mailed out 2.7 billion pre-approved credit card applications. Credit card delinquencies soared in 1995, reaching a ten year high. Three point six percent of all credit card accounts were delinquent and personal bankruptcies increased by 23% compared to 1994. Many people interviewed for the article said that they charged too much to their credit cards because they had large credit limits, but later were unable to pay even the minimum required payments. In some cases, the minimum required payments were greater than the persons’ income.

Clearly, the increasing personal bankruptcies and problems people face in paying credit card bills are a reason for concern. This paper studies the cause of large interest payments that make it more difficult for people to repay their credit card bills because the amounts to be paid back to the card company increase over time.

8.2 Credit Card Billing

Credit card companies send a statement to every card user once a month. The user has one month to pay the bill. During the one month allowed to pay the bill, no interest is charged on the card purchases made during the period covered by the statement. Therefore, if the card user always pays the entire amount on the statement within one month, the “Balance Payable” will be zero for the next billing period, and no interest will ever be charged. For example, the statement listing all the credit card purchases for the month of January will be mailed to Joe on about February 15. Joe is allowed until March

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[5] Laurie Hays, “*Banks’ Marketing Blitz Yields Rash of Defaults.*” The Wall Street Journal, Wednesday 25, 1996, page B1.

15 to pay the amount on the statement. Assume that at the beginning of January, Joe had a "Balance Payable" equal to $0.00. On February 15, for example, he receives the statement for $600.00. If Joe pays the $600.00 before March 15, he will not be charged any interest. If Joe continues the practice of paying the entire amount on the statement within a month of receiving the statement, he will never have to pay any interest. Therefore, it is possible to use a credit card and have a standard of living exactly equal to the paycheck.

In this paper, it is assumed that Joe does not have to pay an annual fee for his credit card. Many credit card companies require card users to pay an annual fee to use their credit card. In recent years, however, many credit card companies have canceled the annual fee to encourage people to use their card. It can, therefore, be assumed that Joe does not pay an annual fee on his card.

Another benefit of getting a credit card is the advertisement and discount coupons credit card companies usually send with the card. Coupons often give the card user frequent flier miles, airline discount coupons and other discount and gift coupons. If used, the coupons can save the card user a lot of money. There are also other services provided by credit cards, such as buyer replacement options, cash withdrawal, and other special deals which have been ignored in this paper.

Therefore, it is beneficial to own credit cards, but credit cards should not be abused, and the suggested policy of always paying the entire balance should be followed.

8.3 Equations: The Credit Card Model in Figure 8

Balance_Payable(t) = Balance_Payable(t - dt) + (credit_card_purchases) * dt
INIT Balance_Payable = 0
DOCUMENT: The "Balance Payable" is the amount of money owed to the credit card company by the card user.
UNITS: Dollars

INFLOWS:
credit_card_purchases = available_credit*SPENDING_FRACTION
DOCUMENT: DOCUMENT: "credit card spending" is the total amount charged on credit cards, and is a fixed fraction, the "SPENDING FRACTION" of the "available credit."
UNITS: Dollars / Month

available_credit = CREDIT_LIMIT-Balance_Payable
DOCUMENT: DOCUMENT: It is equal to the difference between the “CREDIT LIMIT” and “Balance Payable.” The available credit is the maximum amount of money the card user can charge on the card at the time.
UNITS: Dollars

cash_purchases = PAYCHECK-interest_on_balance
DOCUMENT: DOCUMENT: The purchases made each month with the money left from the "PAYCHECK" after paying the “interest charges.”
UNITS: Dollars / Month

CREDIT_LIMIT = STEP(6000,6)
DOCUMENT: DOCUMENT: The maximum amount Joe can charge on his credit card. It is the maximum value of the “Balance Payable.”
UNITS: Dollars

interest_on_balance = Balance_Payable*INTEREST_RATE
DOCUMENT: The interest charged on Joe’s “Balance Payable” by International Express.
UNITS: dollars / Month

INTEREST_RATE = 0.015
DOCUMENT: DOCUMENT: The fraction of the “Balance Payable” charged as interest per month.
UNITS: I / Month

PAYCHECK = 2000
DOCUMENT: DOCUMENT: The “PAYCHECK” is the money earned each month.
UNITS: Dollars / Month

quality_of_life = credit_card_purchases+cash_purchases
DOCUMENT: DOCUMENT: The quality of life is how much the card user purchases at any time.
UNITS: Dollars / Month

SPENDING_FRACTION = 0.1
DOCUMENT: DOCUMENT: The “SPENDING FRACTION” is the fraction of the “available credit” the user spends on credit purchases each month.
UNITS: 1 / Month

8.4 Estimating Model Behavior

The flow of “credit card purchases” is highest when “available credit” is highest. The “available credit” is highest when “Balance Payable” equals zero, that is at six months.

"Credit card purchases" increase the "Balance Payable," which reduces the "available credit," which in turn reduces the "credit card purchases." Lower "credit card purchases" still increase the "Balance Payable" but by a smaller amount than in the previous cycle because the amount of "credit card purchases" has declined. Therefore, the "credit card purchases" flow is constantly decreasing and exhibits asymptotic decay. The "Balance Payable" is the accumulation of the "credit card purchases" flow; therefore, "Balance Payable" increases and approaches a maximum value asymptotically. "Balance Payable" increases fastest as soon as Joe receives his credit card, and the "credit card purchases" are largest. The maximum value of "Balance Payable" is the "CREDIT LIMIT." Therefore, the "Balance Payable" asymptotically approaches the "CREDIT LIMIT," while "credit card purchases" asymptotically approach a value of zero dollars per month.

Estimating the behavior of "Balance Payable" and "credit card purchases" is not difficult. A first-order negative feedback loop[6] drives the behavior of the "Balance Payable" and "credit card purchases." The behavior of "quality of life" and "cash purchases" is more difficult to estimate.

Looking at the model and the equations, it is clear that:

? as "Balance Payable" increases over time, "interest on balance" increase;

? as "interest on balance" increase, "cash purchases" decrease.

Therefore, "cash purchases" and "credit card purchases" decline asymptotically over time. Hence, the "quality of life" also decreases.

"Interest on balance" is a fixed fraction of the "Balance Payable." Therefore, "interest on balance" also exhibits asymptotic growth. Therefore, "cash purchases" decline asymptotically and approach the value equal to "PAYCHECK" minus the equilibrium value of "interest on balance."

The "interest on balance" is highest when the "Balance Payable" is at the highest value, that is, equal to the "CREDIT LIMIT." Therefore, the maximum "interest on

[6] For an explanation of first-order negative feedback loops, read: Helen Zhu, 1996. *Beginner Modeling Exercises: Mental Simulation of Simple Negative Feedback* (D-4536), System Dynamics in Education Project, System Dynamics Group, Sloan School of Management, Massachusetts Institute of Technology, March 25, 1996, 23 pp.

balance" is equal to the "CREDIT LIMIT" times the "INTEREST RATE." Using the equations, the equilibrium value of "cash purchases" can be calculated.

After estimating the behavior of the models from Figure 7 and Figure 8, the reader should run the models and compare his graphs with the graphs of the behavior of variables after running the models.

8.5 Interest charges on credit card balances

Credit card companies calculate the interest rate in two steps. The annual interest rate (18% in the system this paper studied) is called the Annual Percentage Rate (APR). The APR is calculated by adding the U.S. prime rate and the variable rate. The U.S. prime rate is determined by the financial markets, and the credit card companies have no control over the prime rate value. The variable rate is set by the company. In May 1997, at the time of writing this paper, the prime rate was about nine percent, and most credit card companies charged a variable rate of about nine percent. Therefore, the APR for most credit cards was about 18% in May 1997[7].

Interest charges on loans are usually compounded. The formula for compound interest is:

Final Amount = Initial Amount * (1 + interest rate)^$^{\text{Time periods}}$

Irrespective of whether the "annual interest rate" or the "monthly interest rate" is used, the "Final Amount" will be the same for a given "Initial Amount" and "interest rate."

Consider a time period of 1 year or 12 months.

Using the "annual interest rate," "Time" is equal to 1. Using the "monthly interest rate," "Time" is equal to 12. Let the "annual interest rate" = 18% = 18 ? 100 = 0.18.

Irrespective of whether the "annual interest rate" or the "monthly interest rate" is used in the calculations, the "Final Amount" and "Initial Amount" will be the same. Two

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[7] Credit card companies usually offer a wide range of credit cards for different users. Different credit cards offered by the same company will have different APRs. For most cards, the APR is about 18%. For credit cards with very large credit limits and cards that offer many options and special services and features, the interest rate may be higher than 18%.

equations can be formulated. The time period when the monthly interest rate is used willbe “12,” because there are 12 months in a year.

Equation 1: Final Amount = Initial Amount * (1 + annual interest rate)^1

Equation 2: Final Amount = Initial Amount * (1 + monthly interest rate)^{12}

Therefore, (1 + annual interest rate)^1 = (1 + monthly interest rate)^{12}

(1 + 0.18) = (1 + monthly interest rate)^{12}

Hence, the monthly interest rate is 0.01388, or 1.39%

8.6 Other forms of Credit and their expenses

Credit cards are only one of many forms of credit commonly used. Mortgages, bank loans, corporate and government bonds are other common forms of borrowing money. Various types of credit are different from each other, and are used for various purposes. Interest, however, has to be paid on every kind of loan. Due to the interest payments, the money that has to be paid back to the lender is more than the money borrowed.

Many countries have a budget deficit for many years. The government spends more money than it collects. The difference between the expenses and revenues is paid by taking loans from other nations and organizations and by issuing bonds. Bonds are financial instruments used to borrow money in financial markets. The amounts borrowed by countries can be large. Soon, the countries have to spend large sums of money just to service the debt, that is, pay the interest on the debt. As the amount of the debt increases, it becomes more difficult to repay the loan, and the interest payments become larger. Therefore, governments face the same problem as people who use credit cards carelessly, but on a much larger magnitude. [8]

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[8] Under certain economic conditions, such as rapid growth, it may be more beneficial to the economy if the government borrows money and runs a deficit rather than balances the budget. Most countries that run a deficit, however, do not face these special conditions.

Vensim Examples :The Credit Card Model

By Aaron Diamond

October 2001

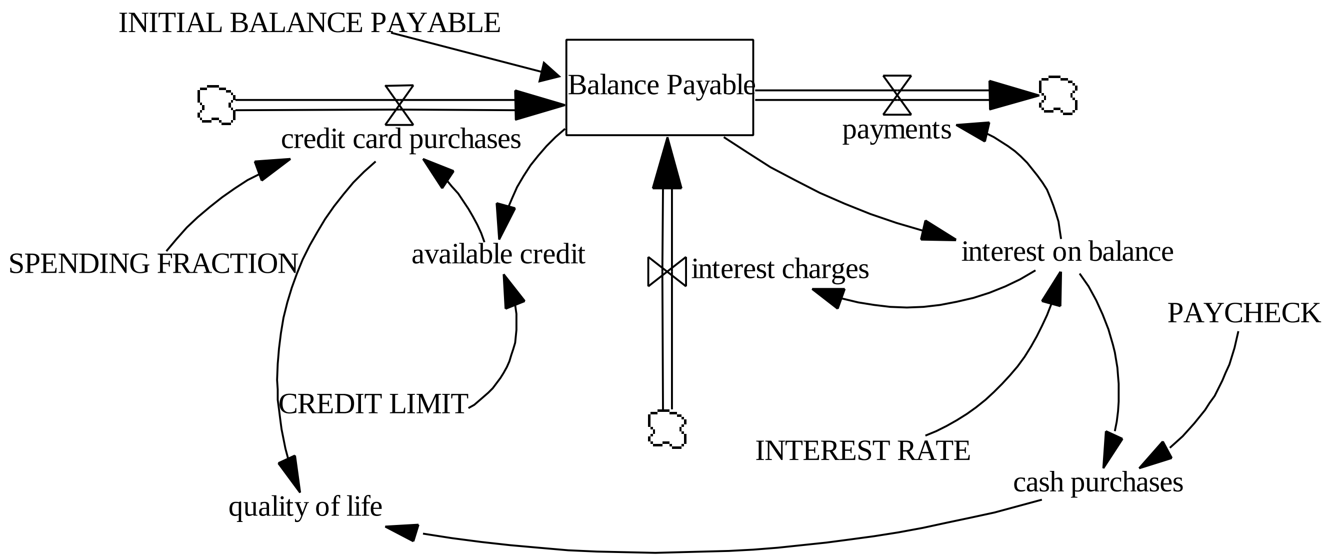

Figure 10: Vensim Equivalent of figure 7: Model of the credit card system.

Documentation for the credit card model

(01) available credit=CREDIT LIMIT-Balance Payable

Units: dollars

"Available credit" is the difference between the "CREDIT LIMIT" and the "Balance Payable". The "available credit" is the maximum amount of money Joe can charge to his credit card at the time.

(02) Balance Payable= INTEG (credit card purchases+interest charges-payments, INITIAL BALANCE PAYABLE)

Units: dollars

The "Balance Payable" is the amount of money Joe owes to International Express

(03) cash purchases=PAYCHECK-interest on balance

Units: dollars/Month

The purchases made each month with the money left from the "PAYCHECK" after paying the "interest charges."

(04) credit card purchases=SPENDING FRACTION*available credit

Units: dollars/Month

"Credit card purchases" is the amount Joe charges on his credit card each month, and is a fixed fraction, the "SPENDING FRACTION" of the "available credit".

(05) CREDIT LIMIT=STEP (6000,6)

Units: dollars

The maximum amount Joe can charge on his credit card. It is the maximum value of the "Balance Payable."

(06) FINAL TIME = 72

Units: Month

The final time for the simulation.

(07) INITIAL BALANCE PAYABLE=0

Units: dollars

(08) INITIAL TIME = 0

Units: Month

The initial time for the simulation.

(09) interest charges=interest on balance

Units: dollars/Month

"Interest charges" is the interest charged each month on the "Balance Payable."

(10) interest on balance=Balance Payable*INTEREST RATE
Units: dollars/Month
The interest charged on Joe's "Balance Payable" by International Express.

(11) INTEREST RATE=0.015
Units: 1/Month
The fraction of the "Balance Payable" charged as interest per month.

(12) PAYCHECK=2000
Units: dollars/Month
The "PAYCHECK" is the money earned each month.

(13) payments=interest on balance
Units: dollars/Month

(14) quality of life=cash purchases+credit card purchases
Units: dollars/Month
The quality of life is how much the card user purchases at any time.

(15) SAVEPER = TIME STEP
Units: Month
The frequency with which output is stored.

(16) SPENDING FRACTION=0.1

Units: 1/Month

The "SPENDING FRACTION" is the fraction of the "available credit "Joe spends on "credit card purchases each month.

(17) TIME STEP = 0.0625

Units: Month

The time step for the simulation.

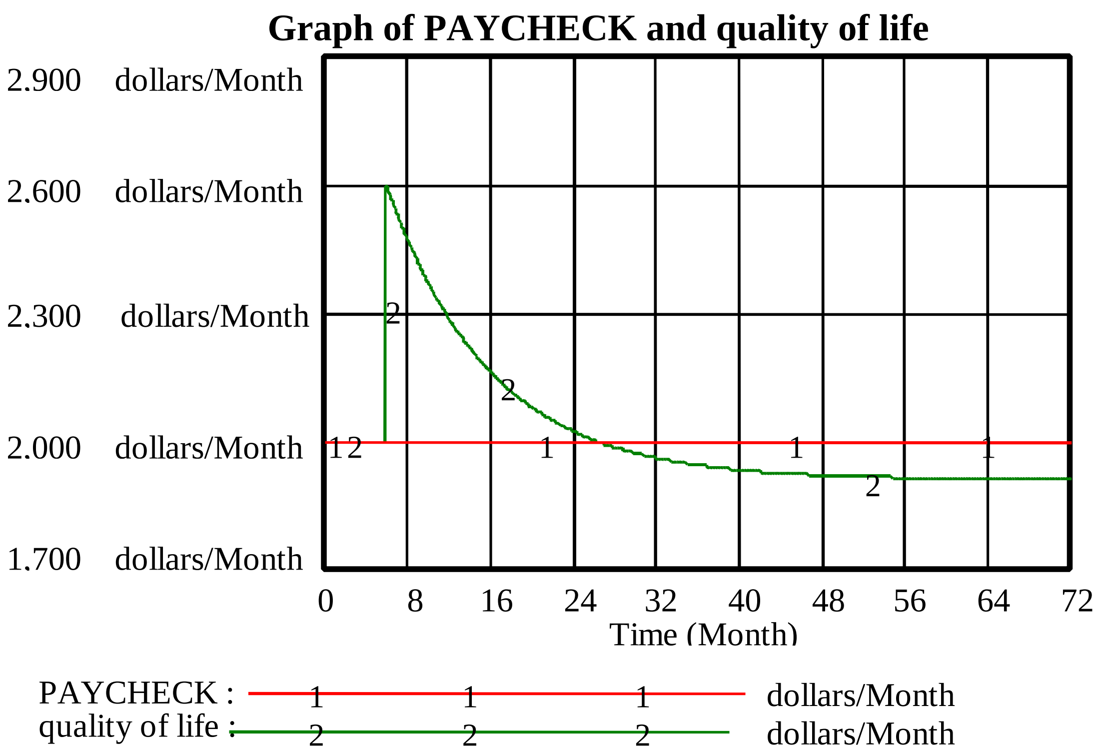

Figure 11: Vensim Equivalent of Figure 9: Behavior of “quality of life.”