Last Name: _____ First Name: _____ Student ID #: _____

Modeling using functions:

Canadian household mobile subscription rates: trends, models and predictions

PROJECT OVERVIEW

Objective:

The objective of this project is to apply knowledge and understanding of fundamental characteristics of basic functions and their transformations in order to create plausible models of data sets and study their behaviour. Specifically, you will investigate the data compiled by Canadian Radio-television and Telecommunications Commission on Canadian landline and mobile service subscribers per 100 households, with focus on households with a mobile subscription.

Project submission must be the **result of individual work**. Consultation with others, providing work to another person or using someone else's work, in part or in whole, are not allowed in this project. All questions and requests for guidance must be directed to the course instructor during office hours or by e-mail, or the teaching assistants during their office hours.

Deliverable: This document, completed in Microsoft Word format (Equation tool must be used for mathematical expressions) with answers to questions provided sequentially as they are posed throughout the Tasks list.

Submissions must demonstrate your

- understanding of major characteristics of basic functions and their transformations,
- application of mathematical analysis skills to create plausible models of data sets and study their behavior, and
- employment of communication skills in support of choices, decisions and predictions

The product must demonstrate all tasks have been completed (see next section) and must include answers to all questions posed within the tasks, justified fully using mathematical analysis techniques (algebra, functions and calculus) and supported through visual representations (relevant data tables; images of graphs created through Desmos).

Submission requirements:

- Submission must be in form of a single document in PDF format, stating clearly author's student ID number, last name and first name at the top of every page.
- The document must be submitted through Canvas by posted deadline.

IMPORTANT: Save your work and save it often. By registering with Desmos, you will be able to save your work for later. If you prefer not to register, you can save your work by creating and saving a link to the last state of your graph in Desmos through Share Graph tool.

☐ **I have read and understood the information above (check the box to confirm)**

Attribution: Data used in this project is provided by Government of Canada under Open Government Licence – Canada (https://open.canada.ca/en/open-government-licence-canada)

TASKS

Sourcing the data

1. Retrieving the data

a. Using a web browser, locate the Canadian Radio-television and Telecommunications Commission's *Communications Monitoring Report 2018* on *Communications Services in Canadian Households: Subscriptions and Expenditures 2012-2016*. Briefly (in one to three sentences) state what the report is about and include the website address.

b. Read Quick Facts and briefly state what they say about trends in household communication services subscriptions.

c. Read the summary on what communication services Canadian households use and briefly state what additional trends are identified.

d. On the webpage, follow the link to the data source for the report (linking to Government of Canada - Open Data) and briefly state the description of the data in the publication and the publisher of the data.

e. State the licence under which the data is published, read its description and explain briefly why you are allowed to use this data set for the project and any requirements related to use.

f. Download the XLSX file containing the data on Communications Services in Canadian Households Subscriptions and Expenditures. Locate Table 1.1 and copy it into the document here.

2. Understanding the data

a. Download the data dictionary (DOCX or TXT format) and read it.

b. Review the information in Table 1.1 and explain what the data is describing.

c. What are the input values and the output values, and their units of measurement?

d. What appear to be trends in the data, if any? Are there any holes or inconsistencies in the data and, if yes, how can they be explained?

e. Select the rows and columns containing the data (including the headings) and use the Excel Charts tool to create a scatter plot of the data. Give it a title, add axis titles and copy it here.

f. Briefly provide your prediction for each of the categories as many years pass. Which mathematical concept describes this process?

Modeling the data for household mobile subscription rates

3. Choosing the model

a. Create a new Excel spreadsheet containing the Mobile subscription data from Table 1.1. Change the Year column heading to Years since 2004 and update the data in the column accordingly.

b. Open a new graph in the Desmos Graphing Calculator and copy the data into the first line. Rename the independent and dependent variable in the Desmos table to t_1 and M_1, respectively. Using the Graph Settings tool (wrench icon in top right corner), add arrows and label the axes appropriately. Using the Share Graph tool (top right corner), export and insert the image of the resulting graph below. Reduce its dimensions to 2'' in height.

c. What type of function do you think might model the data reasonably well and why? Describe the characteristics of that function type that match the apparent behavior of the data.

d. Which transformations you expect must be applied to the basic type of that function to obtain the function that models the data reasonably well?

e. State the general form of the function $M(t)$ for the household mobile subscription rate t years from 2004 that you believe would best model the data.

4. Creating the model function using regression

a. Go to Help tool (? icon) and run the Regression Tour. If needed, go to Video Tutorials and watch a video on Regressions.

☐ **I completed the Regression Tour (check the box to confirm)**

b. Using what you learned about creating the regression models using Desmos, create the regression model using the type of function you chose above. Using the Share Graph tool (top right corner), export and insert the image of the resulting graph below, resizing it to 2'' in height.

c. Using the regression function parameters given by Desmos, write below the function $M(t)$ represented by that regression model.

d. Does this model provide a reasonable model for the data and why?

e. Using the Share Graph tool (top right corner), copy below the link to your graph.

5. Adjusting the model as necessary by considering context

a. Do you think that, over time, all of the Canadian households will have a mobile subscription, and why? Make a prediction for % of households that will have a mobile subscription as years pass.

b. Looking at the regression function $M(t)$ that models the rate of household mobile subscriptions data over time since 2004, how does that model match with your prediction, both by looking at the graph of the function and by analyzing the function using mathematical analysis techniques (hint: limits)?

c. Which parameter would have to change in the function $M(t)$ to match it with your prediction, why, and to what value?

d. Recreate the model using Desmos with this change. Using the Share Graph tool (top right corner), export and insert the image of the resulting graph below, resizing it to 2'' in height.

e. Does the new regression function appear to model well the known data, while agreeing with your prediction? Briefly explain your reasoning.

f. If applicable, change the parameters in $M(t)$ to reflect the revised regression model and write the new formula for $M(t)$ below.

g. Using the Share Graph tool (top right corner), copy below the link to your graph.

6. Adjusting the model as necessary by considering additional information

a. Consider the data on household mobile subscriptions prior to 2004. Download the data from the 1997 – 2009 Survey of household spending on household equipment from Open Canada. Open the CSV file and use the following filters (Data – Filter Excel tool) to retrieve the data on Canadian household mobile subscription rates:

- GEO: Canada
- Household equipment: Households having a cellular telephone
- UOM: Percent

Copy the resulting table below.

b. Does this data match the data you already have on household mobile subscription rates for years 2004 to 2016? Briefly state what might explain the discrepancies, if any.

c. Add the data for 1997 to 2003 to your table containing household mobile subscription rates for 2004 to 2016, making sure that you enter the appropriate values in the Years since 2004 column. Copy the new data table below.

d. Copy the new data set to a new line in the existing Desmos graph containing your work on household mobile subscription rates. Using the Share Graph tool (top right corner), export and insert the image of the resulting graph below, resizing it to 2'' in height.

e. Does the regression function $M(t)$ you used to model household subscription rates appear to model well the expanded data set? Briefly explain your reasoning.

f. Create a new regression model that incorporates the expanded data set and models your prediction for mobile subscription rates as years pass. Using the Share Graph tool (top right corner), export and insert the image of the resulting graph below, resizing it to 2'' in height.

g. Consider the history of cellular phone use, particularly in Canada, by reading Complete Visual History of Cellphones and Cellphones mark 30 years in Canada. Which of the two models you created would be a better reflection of the trends since the introduction of mobile phones to Canadian society, and why?

h. If applicable, change the parameters in $M(t)$ to reflect the revised regression model and your long term predictions, and write the new formula for $M(t)$ below.

i. Using the Share Graph tool (top right corner), copy below the link to your graph.

Making predictions

7. Household mobile subscription rates

a. Using the model you developed for household mobile subscription rates, predict the percentage of households that will have a mobile subscription in year 2025, in 2030 and in 2050. Show your calculations.

b. What are the projected rates of change in the household mobile subscription rates in 2025, in 2030 and in 2050? Show your calculations and interpret the results.

c. Considering the impact the development of cell phones had on landline subscriptions starting 30 years ago, how likely is that your model's prediction for household mobile subscription rates and their growth in 2050 and beyond is accurate, and why?

8. Modeling the number of households with mobile subscriptions

a. To obtain the data on number of Canadian households over years since 2004, follow the link to the Statistics Canada data on Distributions of household economic accounts, number of households, by income quintile and by socio-demographic characteristic. Click on Add/Remove reference period and change the reference period to years 2004 to 2016. Click on Apply, then Download options, then CSV Download as displayed (excluding accompanying symbols).

Change the text in the Income Quintile cell to Years since 2004 and fill the rest of the cells in the row accordingly. In the row below, enter Number of Canadian households (in millions) and fill the row for each year since 2004 using the data in the All quintiles row, dividing it by a million. Select the two rows and create the scatter chart representing the number of Canadian households (in millions) in the years since 2004. Add the horizontal axis title and copy the chart below.

b. Looking at the data, what type of function would best model the trend in the number of Canadian households since 2004? Describe the characteristics of that function type that match the apparent behavior of the data.

c. State the general form of the function $H(t)$ for the number of Canadian households t years from 2004 that you believe would best model the data.

d. Add a trendline to the chart in Excel that reflects your choice of the model type and display the equation for $H(t)$ on the chart. Write below this equation.

e. What does $H(t)$ tell you about the rate of change in the number of Canadian households?

f. Using your models $M(t)$ and $H(t)$ for the household mobile subscription rates and the number of Canadian households, determine the function $H_M(t)$ modeling the number of Canadian households with a mobile subscription t years from 2004. Write $H_M(t)$ below.

g. Using the model $H_M(t)$ for the number of Canadian households with mobile subscriptions t years from 2004, predict the number of households that will have a mobile subscription in years 2025 and 2030. Show your calculations.

h. What are the projected rates of change in the number of households that will have a mobile subscription in 2025 and 2030? Show your calculations and interpret the results.

i. Suppose that, due to new technology developments in communications, the household mobile subscription rate in 2050 is 95% and is decreasing at the rate of 5% per year. Suppose further that the number of Canadian households continues to grow at the same rate as today. Find the rate of change in the number of households with a mobile subscription in 2050. Show your calculations and interpret the result.

REPORT

9. Summary of findings

Write a short summary of your findings (up to one page in length), including a brief description of the overall task, information found and conclusions made. You may use the three task subsections as a guide, writing a paragraph (or two, if necessary), on each (Sourcing the data, Modeling the data for household mobile subscription rates, Making predictions).

THE END

IMPORTANT: BEFORE SUBMITTING, READ AGAIN THE SUBMISSION REQUIREMENTS ON PAGE 1 AND ENSURE ALL REQUIREMENTS ARE MET.

Sources:

Canadian Radio-television and Telecommunications Commission. Communications Services in Canadian Households: Subscriptions and Expenditures 2012-2016. Published under the Open Government Licence – Canada. Retrieved from https://crtc.gc.ca/eng/publications/reports/policymonitoring/2018/cmr1.htm on February 29, 2020.

Canadian Radio-television and Telecommunications Commission. Communications Services in Canadian Households Subscriptions and Expenditures. Published under the Open Government Licence – Canada. Retrieved from https://open.canada.ca/data/en/dataset/f7aea609-4a2c-4e20-ba1a-08e0ad2789d1 on February 29, 2020.

Statistics Canada. Table 36-10-0101-01 Distributions of household economic accounts, number of households, by income quintile and by socio-demographic characteristic. Retrieved from https://doi.org/10.25318/3610010101-eng on February 29, 2020.

Watch The Incredible 70-Year Evolution Of The Cell Phone. Justin Meyers, WonderHowTo. Published by Business Insider on May 6, 2011, 10:47 AM. Retrieved from https://www.businessinsider.com/complete-visual-history-of-cell-phones-2011-5 on February 29, 2020.

Cellphones mark 30 years in Canada. Peter Henderson, The Canadian Press. Published by the Canadian Broadcasting Corporation on Jun 29, 2015 1:44 PM ET (last updated: June 29, 2015). Retrieved from https://www.cbc.ca/news/technology/cellphones-mark-30-years-in-canada-1.3132058 on March 1, 2020.