NASCAR® Pit Strategy

STEM Lesson for TI-Nspire™ Technology

Objective: Analyze data using graphs, regressions, and area under the curve; and use the results to asses the best pit strategy for the last 30 laps of a NASCAR race.

About the Lesson: NASCAR teams track lap times for their driver and other cars to find out who is gaining and losing. This information is critical to devising a pit strategy – when to come in and what to do. One of the most critical decisions a race team has to make is how many tires to change and when. In such harsh conditions, tires may only last about 100 laps. Worn tires slow the car down so it is up to teams to decide how to handle the trade-off: Changing tires requires time but not adding tires means your car goes slower.

Your team is in the last 30 laps of a race. Though your team is balancing many variables when making decisions (such as how much fuel to add and what tire pressure to use), you are only responsible for suggesting how many tires to change: 2, 4 or don't pit.

Materials: *Pit_Strategy.tns* TI-Nspire file
Student worksheets

Prerequisite skills: The students should be proficient at scatter plots, trend lines, and linear regressions. For calculus, it would be helpful if the students had a basic knowledge of the concept of finding the area under a curve. It will also be necessary to explain the general pit strategy options available to a NASCAR team on a pit stop. The team can change no tires, right side tires, or all four tires. The more tires you change, the more time it takes to pit but the faster the lap times will be after the pit stop.

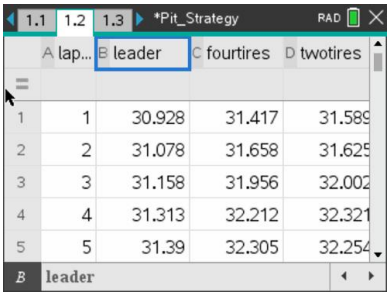
Teacher Tip: This activity is designed for use in a Calculus classroom but can be used in an Algebra classroom by omitting discussion of integrals and examining only the concept of area under the curve and increasing/decreasing functions in place of rates of change.

Analysis:

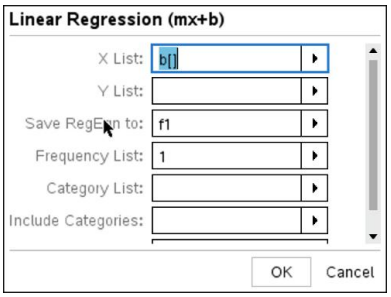
1. On your handheld, go to My Documents and open the file named *Pit_Strategy.tns.*

2. Use ctrl ▶ to move to page **1.2**.

The data is 15 laps from the 2011 race at Las Vegas Motorspeedway. The first column is the lap number, and the second column is lap times for the race leader. The third and fourth columns are a 15th place car with 4 new tires and a 15th place car with 2 new right side tires.

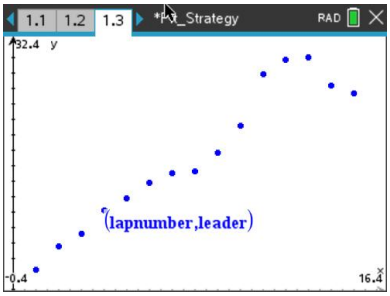


3. Do a linear regression analysis on the leader data. Press menu then choose **Statistics > Stat Calculations > Linear Regression(mx+b)**. The regression template will pop up. Remember to press tab to switch boxes. Click the arrow at the right of each box to access the drop down menus. Choose *lapnumber* for the X List and *leader* for the Y list. Tab through the other options until you get to 1st Result Column. Click beside the letter and change it to 'f' if it isn't already. Click OK.

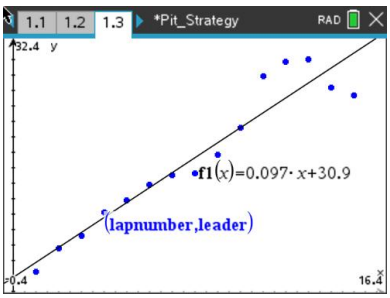


4. Move to page **1.3**. Press menu then choose **Graph Type > Scatter Plot**. Notice the function bar at the bottom of the screen changes from f1 to s1.

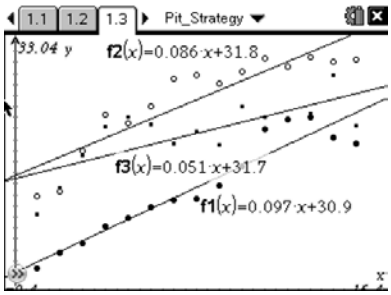
5. Press var and choose *lapnumber*. Press ▼ then var and choose *leader*. Press enter. Now adjust your window to view the data by pressing menu then choosing **Window/Zoom > Zoom – Data**.



6. Now graph the regression line. Press menu then choose **Graph Type > Function**. Press ▲ to see your function in f1 then press enter. You should see your line on top of your data points.



7. Repeat this process to analyze *lapnumber* vs. *fourtires* and *lapnumber* vs. *twotires*. Remember to change the column letter in the 1st Result Column box of the regression template. Always use the next **empty** column and don't overwrite data. Each scatter plot will use a different symbol. Hover over a label and press ctrl then ☜ to move the labels to see the data better. You can also click a label and press del to erase the labels completely.



   Notice how changing just the right side tires at Las Vegas yields similar lap times to changing all four for the first 5-6 laps, then starts to fall off and is slower than 4 fresh tires on a longer run.

8. It takes about 8 seconds to change 2 tires and 14 seconds to change 4 tires. If there were 10 laps left in a race and you had to make a pit stop, how many tires would take? Explain.

   Answer: All student answers should be considered; but with this data, 2 tires would be the best call. The lap times are close to the same as 4 tires for 5-6 laps, and the difference in lap times after 7-10 laps would be less than the time it takes to change 2 tires compared to 4 on pit road.

Navigator Tip: *Quick Poll the students for their answers to #8 and show the results to start a good discussion and to make sure the students understand the concept.*

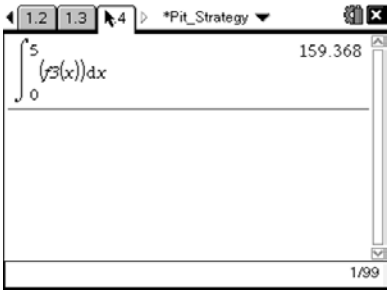
Teacher Tip: *Two NASCAR cars that are capable of the same lap time will not necessarily run the same lap time on the track. A car that is leading will tend to be faster because it has more down force and grip because it is not running in dirty air behind another car.*

The predictive lap time equations can be used to help decide on tire strategy. The total predicted elapsed time for the car is defined as the area under the predicted lap time curve. The area under the curve can be calculated by taking the integral of the equation of the lap time curve.

9. Move back to page **1.2**. What is the actual total elapsed time for the first 5 laps of the race on 4 fresh tires? Press the (=) key to bring up the scratchpad for calculations.

   Answer: 159.54 seconds (Add the first five lap times in column C.)

10. Move to page **1.4**. Now calculate the predicted total elapsed time for the first 5 laps using an integral expression. Press (menu) then choose the definite integral template and enter 0 for the lower limit, 5 for the upper limit, and **f1(x)** for the expression. Don't forget the *x* after the *d* which tells the handheld to integrate with respect to *x*. Press (enter).



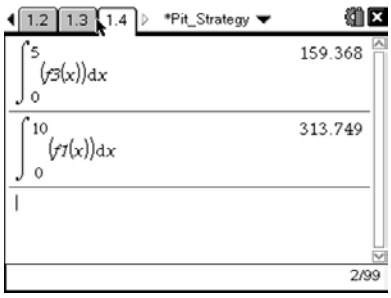
11. What is the difference between the predicted five lap elapsed time and the actual elapsed time for the first five laps of the race with 4 fresh tires?

    Answer: The calculation predicts a slightly faster time, but it is really accurate in this region.

Teacher Tip: *This would be a good time to talk about the r^2 value and how it was really good for this data set and thus the predicted and actual lap times are close.*

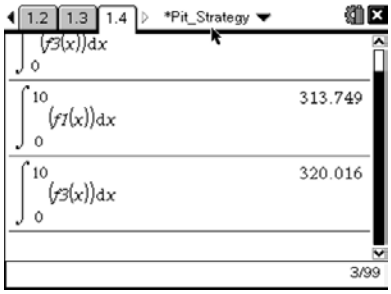
12. What will the leader's elapsed time after 10 laps be? Write the integral you used.

    Answer: 313.749 seconds



13. Use the 4-tire data to predict a car's total elapsed time after 10 laps with a 4-tire pit stop? Write the integral you used.

Answer: 320.016 seconds



14. How far (in seconds) behind the leader will you be after 10 laps?

Answer: 320.016 - 313.749 = 6.27 seconds

Navigator Tip: *Quick Poll the students for their answers to #14 and show the results to start a good discussion.* You can also talk about how much different the r^2's are in the two equations.

'Short pitting' is a pit stop procedure used by teams to try to makeup ground on the leader when they are not as fast as the leader. The car will run quicker lap times on new tires, so the team will pit well before they need fuel to put new tires on the car to make up time on the leader while the leader is running slower lap times. When the leader finally pits for fuel and tires, the chasing car will be much closer to the leader if not ahead. The risk with this strategy is that the pit stop takes a lot of extra time, and if the caution comes out before the leader pits later in the race, the chasing car is in jeopardy of going 1 lap down.

15. If the leader pits for 4 tires on lap 40, what is the best tire strategy if your car is going to pit on lap 20? For a four tire pit stop, add 37 seconds to your total elapsed time. For a two tire stop add 30 seconds to your total elapsed time.

Answer: Calculate the integral for the 4 tire stop over 0-20, double it, and add 37 seconds. Do the same for the 2 tire predicted equation, but add 30 seconds. For the leader's elapsed time, do the integral from 0-40 and add 37 seconds.

Leader- 1350.07 s, 4 tire- 1327.3 s, 2 tire- 1335.35 s

The 4-tire stop comes out ahead by 22.77 s, and the 2-tire stop comes out ahead by 14.72 s.