September 28, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 440 Project Proposal for Auto-adjustable Spoiler System

Dear Dr. Rawicz:

The enclosed document is a proposal for our engineering capstone project for "Auto-adjustable Spoiler Control System". The project motivation is to improve fuel efficiency and road performance of a high speed car by the optimal utilization of atmosphere. With this vision, we purpose to design a multi-functional and highly-compatible car spoiler control system to provide driver a wonderful driving experience.

In our proposal, we provide an overview of our product and discuss design considerations, potential, markets, costs, project milestones and planning as well as further information about our company and team members. Also, we list the risks and benefits of our product and compare our system with alternatives currently available.

Veroptimal Solutions is composed by four engineering students from different streams: Zhengdong Cao, Yueying Li, Tianye Zhou and Tianlin Yang. For any questions or concerns about our proposal, please feel free to contact me by phone at 778.317.4405 or by email at zcao@sfu.ca.

Sincerely,

Zhendong Cao
President and CEO
Veroptimal Solutions

Enclosure: Proposal for Auto-adjustable Spoiler Control System

# Auto-adjustable Spoiler Control System

## Project Proposal

**Project Team:**
Zhengdong Cao **CEO**
Yueying Li **COO**
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**Submitted to:**
Dr. Andrew Rawicz
Mr. Steve Whitemore
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**Issued Date:**
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## EXECUTIVE SUMMARY

One common circumstance is that all vehicles suffer from air drag while driving; but less people are aware of the fact that air drag increases quadratically as speed goes up. A research shows that at 140km/h driving speed, 88.4% of total drag applied on the vehicle is contributed from the air [1]. Another fact which is not obvious to most of drivers is that the rear body of their car is suffering from an aerodynamic lift in range of hundred pounds while driving at highway [2].This significant lift leads to fewer grips of vehicle's back wheels with the ground therefore lowers the vehicle's stability and maneuverability. As a technology being invented and developed for over 40 years, car spoiler is an effective solution to those aerodynamic "headaches".

You may have been impressed by a deluxe sporty car with a high-tech rear spoiler with capability of performing various fancy movements in situations for gaining aerodynamic favors. But more likely you have to give up the dream of owning such a remarkable spoiler on your own car. Though these types of "smart", stylish and versatile spoilers can utilize the air more effectively, they are usually designed as an integrated part a car and rarely sold as an independent unit. Otherwise they are incredibly unaffordable. However, with Veroptimal Solution's latest product "Auto-adjustable Spoiler Control System", or ASCS product, your dream of owning a fancy spoiler on your own will never be so easy to come true.

The ASCS product is not only "smart" and versatile, but also very compatible. Once it is being installed, you can attach your own spoiler onto it since it fits to majority type of spoilers in the market. Our product provides a friendly-looking user interface panel which allows the driver having full control of the spoiler: the operation mode of the entire system can be set to either automatic or manual depends on the user. With automatic mode, the ASCS will automatically adjust itself until the vehicle has reached to the optimal aerodynamic state; it can also detect special scenarios such as emergency brake, downhill driving and slippery road conditions, and do its best to serve for the user. With manual, the ASCS will obey the user's command unless the user is intending for dangerous or invalid actions.

The goal of ASCS project is to enhance the road safety and fuel efficiency while providing drivers a unique driving experience. More importantly, it offers a new option with reasonable price for middle-class consumers. As consequence, Veroptimal Solution is established by four devoted and talented pioneers from diverse engineering streams. With their motivations and the passions towards this project, they transform an idea to a functional and beneficial product.

Veroptimal Soltuion plans to perform research, design, implement, test and troubleshoot within 12 weeks with an estimated budget of 900$ obtained from different funding sources. The details of our idea along with project overview, design solutions, benefits and risk analysis, project planning schedule and commercial prospective will be addressed in this document. By the 13th week, we would like to present our finished prototype in form of group demo to the class faculties.

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# Introduction

When it comes to vehicles, its safety and fuel efficiency has been always the most frequent concerns of automotive customers. Studies on enhancing vehicle's fuel efficiency from aerodynamic aspect came to be increasingly important. The estimation shows that aerodynamic drag is the dominant resistance for vehicles at high speed. Therefore reducing air drag will result in significant decreases in fuel consumption [3]. Car spoiler is an effective engineering solution dealing with several undesirable aerodynamic effects applied on the vehicle. However, normal car spoiler is designed either to reduce the total aerodynamic drag with less downforce, or to offer large downforce but extra external drag onto the vehicle [4]. Figure 1 shows two typical examples of the rear spoiler design aiming for different aerodynamic purposes.

*Figure 1: Two Different Spoiler Designs Aiming for Different Aerodynamic Effects*

The idea of our project is to link benefits from both types of spoiler designs to a single product which is capable of improvements on both vehicle safety and fuel efficiency. Based on a large amount of researches, discussions, simulations, calculations and test works, we have reached a stage to turn the idea into practical and functional prototype, and we will name it Auto-adjustable Spoiler Control System.

The Auto-adjustable Spoiler Control System, or ASCS, consists of three main constituents including the *user interface panel*, *main controller* and *spoiler system*. The proposed functionality and engineering solutions for each constituent will be provided explanations in the rest of proposal. In addition, ASCS provides users with three operation modes: AUTO mode, MANU mode and PREF mode respectively in order to provide users more freedom and sections in terms of control. With our product installed on the rear of the car, governing the aerodynamic performance of the vehicle by controlling the spoiler can never be easier. The user is able to acquire the current status of the spoiler and its associated effects in terms of safety index improvement and fuel efficiency enhancement.

ASCS will be the first product of Veroptimal Solution. The company name "Veroptimal Solution" stands for optimal vehicle aerodynamic solutions as the word "Veroptimal" is just the combination of vehicle, aerodynamics and optimal. We spent some quality time on discussing the proper name for the company name, and narrowing down to a final decision from numerous possible company names such as Evo In Motion(EIM), AeroXtreme.

# System Overview

This project intends to build a controller for car spoilers such that it can adjust the spoiler's height and angle of attack in either automatic or manual way. Figure 2 shows the basic constituents of the Auto-adjustable Spoiler Control System in a system level. The user controls the car spoiler in three different manners by mode selections through the *User Interface Panel*. They are Automatic Mode (AUTO), Manual Mode (MANU) and Preferred Mode (PREF):

- **AUTO**: the *Main Controller* intakes the real timing feedback parameters such as car speed, downforce applied on the vehicle, road condition and even emergency events and then controls the *Spoiler System* so that it helps optimize the aerodynamic performance of the vehicle
- **MANU**: the user can adjust the *Spoiler System* arbitrarily through the *User Interface Panel*
- **PREF**: the *Spoiler System* will move and maintain a specific position set by the user as a favorite

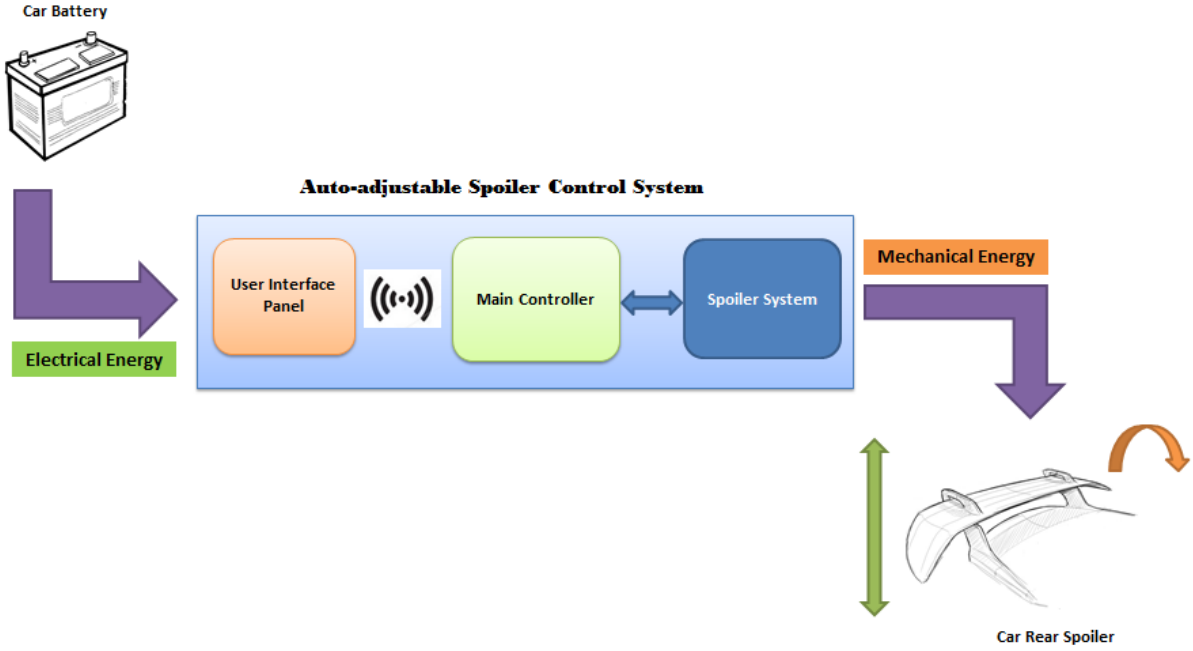


*Figure 2: Conceptual Overview*

The selected mode will be transferred to the *Main Controller* through wireless communication. Once the *Main Controller* received the user's command, it will manage the *Spoiler System* to response in a certain manner defined above. Meanwhile, the *Main Controller* also sends updated information to the *User Interface Panel* for user's information.

# Possible Design Solutions

We divided the project into different sub-systems and evaluated the possible design solutions for each one.

## Main Controller Design

The *Main Controller* is essentially constructed by a central control unit and peripheral circuitry. Initially we intended to design and manufacture a microprocessor chip based PCB board for standardized mass production purpose. However many issues were raised up during the simulation stage of the design. First, we had to add a lot extra ICs into the hardware design to fulfil the requirements, such as DC-DC Converters, Analog to Digital Converters, EEPROM and USB to Serial Adapter. Therefore the cost was raised dramatically high. The second challenge with PCB board is the scheduling. It usually takes weeks to receive the manufactured PCB after we delivered the schematics. If any bugs were caught during verification tests, we may need another hardware design cycle to acquire for the new PCB. The repentance in manufacture within 4 months project schedule may not allow.

## Spoiler System Design

The *Spoiler System* is a mechanical system consisting of power sources and mechanism controlled by the *Main Controller*. For power sources, we can select among DC motors, linear actuators, stepper motors and servo motors. The decision of the power source selection will be mainly based on price, power, durability, dimensions and weight. For mechanism, it is possible to design the kinematic model via a 2 degree of freedom (D.O.F) or a 3-DOF system. The 2-D.O.F system is simpler but requires more power from the power source; the 3-D.O.F eases the burden of the power source however adding more complexity to the mechanism design.

## Communication Methods (User Interface)

Communication between human and machine is considered as a necessary part of the system function. As a result, communication is one of the most important parts in our design. Three communication medias are possible: by wire, by Controller Area Network (C.A.N) bus, by Radio Frequency (R.F) transmission. Wired communication was considered at the initial stage of the design since this is the simplest method. However, we need a 2-meter long cable for power and data transmission. The power loss through the 2-meter cable is about 7% of the entire power consumption during full operation. Last but not least, this manner makes the prototype massy and insufficient to the driver.

# Proposed Design Solution

We evaluated the possible design solutions listed above through calculations, simulative analysis, bench testing and many surveys. Finally, we came up with satisfied solutions for each sub-system.

## Main Controller Design

As a final decision, we adopt Arduino development board as the central control unit instead of microprocessor chip. Arduino is perfectly compatible to our peripheral circuitry without buying any extra ICs; there is also abundant open source code from Internet for different implementations. Consequently, using Arduino as the main control unit allowed us to perform design verification tests much earlier than expected. The trade-off is that we have to abort the plan of manufacturing standardized PCB boards. All in all, for a 4 months project course, Arduino is a more reasonable choice.

## Spoiler System Design

We decided to use linear actuator and DC motor as the mechanical power sources for two reasons. The main reason is that we can easily find linear actuators and DC motors on the market which equip with internal self-locking mechanism. In other worlds, when they are not feeding by the electrical power, the stroke/shaft cannot slide/rotate. Without the self-locking mechanism, the system has to constantly acquiring electric power for the motor to maintain a stable position. Therefore it drains the car battery much faster. The second reason is that linear actuator is able to generate translational motion which is most suitable for the height adjusting feature. Additionally, with feeding the same electric power, DC motor has larger torque than stepper motor and servo motor with cheaper price.

## User Interface Panel

We will use R.F transmission as the primary option for communication. In this way, we can make our system highly independent. First, the user only needs to plug the device into the 12V cigarette socket. Second, all communication between the *User Interface Panel* and the rest of the system is over the air. However, it could be difficult and costly to set up a real-time two way communication system with high immune of interference between Arduinos. In addition, we have a backup plan of using C.A.N bus. The C.A.N bus has high reliability in terms of data transmission since it will integrate our system into the vehicle's area network. However, the only disadvantage is that the user needs to pull out the C.A.N bus connector from the car and manually connect to our system. This disadvantage may be significantly amplified by customers who do not want to disorder any wires from inside of the car.

# Benefits and Risks

## Benefits

The ASCS product aims to enhance the safety index, maneuverability and fuel efficiency of the car by effective utilization of the atmosphere. Customers can make their car more stylish and personalized by installing our product with an affordable price. This product also has a wide compatibility to all different kinds of spoilers. That is, if the customer has already had a spoiler and wishes to make it more “intelligent”, he can simply mount his own spoiler onto our controller instead of spending hundred dollars for an extra unnecessary one.

## Risks

Our product is designed to improve driving safety. However, it has a potential safety risk. ASCS is designated to be mounted onto the car chassis. If it falls off during driving, it will lead to a serious traffic accident. Therefore, in order to minimizing the safety risk, designers must give extra concerns to safety aspect and prepare a back-up mechanism for failures.

ASCS also has engineering reliability risks. When users drive the car to different locations, the changing of surrounding environments such as temperature, humidity and altitude can significantly affect the functionality and the lifespan of ASCS. For example, materials exposed in the air without proper coating may age fast and retire much earlier than expected.

## Commercial Perspective

In 2014, Canada has over 21 million registered small vehicles (car weight less than 4.5 tons) [5] and this huge number of small vehicles will be our product target market. The fact is that there are two types of spoilers available on the automotive market nowadays, fixed type spoilers and active spoilers. Table 1 summarized the features of the mentioned two types of spoilers from a commercial viewpoint.

| Type | Advantage | Disadvantage | Market Share |
|---|---|---|---|
| Fixed Type Spoilers | • High reliability<br>• Simple design and installation<br>• Affordable price | • Unable to adjust according to environmental changes | Civil used passenger cars |
| Active Spoilers | • More effective aerodynamics<br>• Impressive stylish | • Design is more complex<br>• Very expensive | Luxury and sports cars |

*Table 1: Commercial overview of the fixed-type spoiler and active spoilers*

To improve the competitiveness of our product and reduce the market resistance from potential competitors, the idea of "Compatibility" was later introduced into our design philosophy. Our initial design idea was to make an integrated system of which the spoiler and controller belonged to the same unity. This unity was inseparable. It was essentially a multi-functional spoiler hence we named it "Auto-adjustable Spoiler". In this way, both fixed type spoilers and active spoilers would become the potential competitors of our product.

After the concept of "Compatibility" was blooded in, we transformed our original design from a multi-functional spoiler to a more universal spoiler control system. The change means that we only design a control system without the presence of a spoiler. People who already had a fixed type spoiler can easily change it to a fancy, safer and intelligent spoiler with ASCS. This transformation even allows the fixed type spoiler manufacturers become our potential cooperative partner.

# Cost Considerations

## Budget

With careful consideration, the tentative cost for the project development has been outlined in table#. They are categorized into three parts, Electrical, Mechanical and Tools & Materials. The estimated total cost is $900 including shipping fees and 10% contingency.

| Field | Name | Quantity | Expected Cost ($) |
|---|---|---|---|
| Electrical | Arduino Nano | 2 | 70 |
| | Perfboard | 5 | 10 |
| | LCD | 1 | 10 |
| | GPS with Antenna | 1 | 65 |
| | Motor Driver Module | 2 | 60 |
| | 12V Extension Cord | 2 | 30 |
| | switches and buttons | 6 | 30 |
| | Circuit chips | 5 | 20 |
| | pressure sensors | 3 | 50 |
| | angle sensors | 2 | 30 |
| | Tx/Rx modules | 2 | 30 |
| Mechanical | 12V Linear Actuator | 2 | 220 |
| | Mounting Bracket | 4 | 20 |
| | 12V DC Motor and couple | 1 | 70 |
| | Spoiler Model | 1 | 100 |
| | Beam and struts | 6 | 30 |
| Tools & Materials | Glue and Paint | 1 | 15 |
| | Foam Board | 1 | 10 |
| | rope(50m) | 1 | 5 |
| | Plywood sheets | 1 | 20 |
| | 2M cable 24AWG | 2 | 5 |
| Expected total Cost Including shipping | | | 900 |

*Table 2: Estimated Total Budget*

## Source of Founding

Due to the high cost of the budget, Veroptimal Solution is seeking finance help from various sources. First, $50 for each group will be offered from 440 courses. Second, Veroptimal Solution is applying for Engineering Science Student Endowment Fund (ESSEF). Last but not least, all team members are greed to cover the remaining financial costs if the actual cost exceeds the project funding.

# Schedule

Veroptimal Solution proposed and scheduled the development process within 12 weeks. The project time management is shown in both tabular and chart form in Table 3 and Figure 3.

| Name | Start Date | End Date |
|---|---|---|
| ● **Design Process** | 08/15/2015 | 12/10/2015 |
| Research and Planning | 08/31/2015 | 09/29/2015 |
| Topic Decision and Pre-test | 09/04/2015 | 10/04/2015 |
| System Design | 09/07/2015 | 10/05/2015 |
| Hardware Development | 09/11/2015 | 10/28/2015 |
| Mechanical Development | 09/14/2015 | 11/18/2015 |
| Firmware Development | 10/07/2015 | 12/01/2015 |
| Integration | 11/10/2015 | 12/10/2015 |
| Testing and Optimization | 11/16/2015 | 12/15/2015 |
| ● **Documentation** | 09/08/2015 | 12/15/2015 |
| Project Proposal | 09/15/2015 | 10/19/2015 |
| Functional Specification | 10/06/2015 | 10/30/2015 |
| Oral Progress Reports | 10/17/2015 | 11/09/2015 |
| Design Specification | 10/27/2015 | 11/23/2015 |
| Written Progress Report | 11/10/2015 | 12/15/2015 |
| Group Presentation/Demo | 12/10/2015 | 12/12/2015 |
| Engineering Journals | 12/10/2015 | 12/12/2015 |

*Table 3: Project Design and Documentation Timeline*

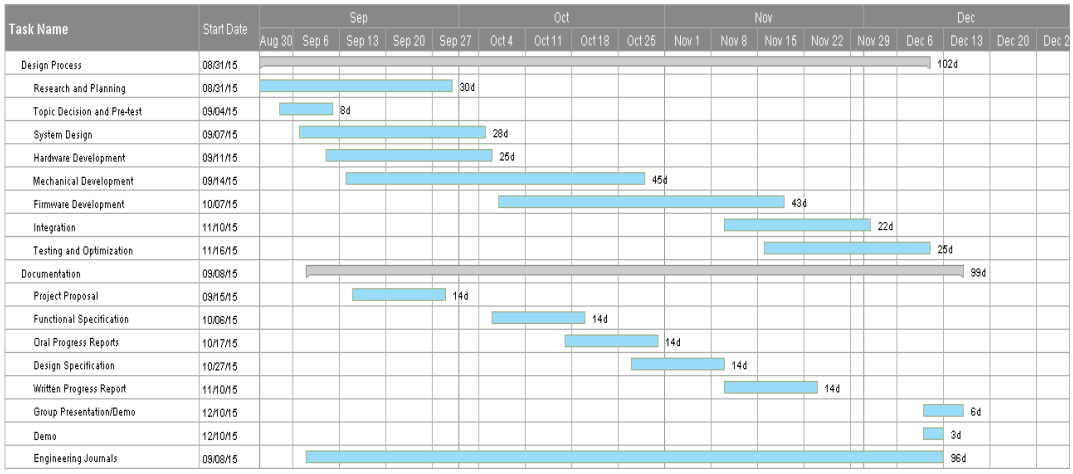


*Figure 3: Gannt Chart of the Project Design and Documentation Progress*

# Company Profiles

### Zhendong Cao – Chief Executive Officer (CEO)

Zhendong Cao is a 4th year Systems Engineering student at SFU. His academic knowledge and practical skills in electronics and mechanics have been well established and tested by the 4 year academic studying and 1 year co-op as a Hardware Designer at NETGEAR and 4 months co-op as a Robot Quality Tester in Shenzhen Institute of Advanced Technology. Technical skills beside, his outstanding ability on time management, decision making and communication has made him very qualified as CEO of Veroptimal Solution. As CEO, zhendong's particular contribution will be on project system level planning, all hardware design and partial mechanical design as well as establishment of effective communication among group members.

### Yueying Li – Chief Operating Officer (COO)

Yueying Li is a 4th year Systems Engineering student in Simon Fraser University. Her 16-month co-op in BlackBerry with various teams provided her knowledge in mobile wireless system, test automation design and development. Her experience with network and wireless protocol analysis as well as test automation development coded with Python and Robot Framework will be an asset for Veroptimal Solution. With her technical background and academic interests, Yueying Li is the perfect choice as COO. As COO, Yueying's contributions will be on systems analysis, design and integration.

### Tianlin Yang – Chief Technical Officer (CTO)

Tianlin Yang is a 4th year Electronics engineering student in Simon Frasser University. He has 4 months' hands on work experience in Schlumberer workshop. In addition, he gets 1-year lab research experience in Lab of Alternative Energy SFU as a lab engineer. During the period of research, he gains a lot of experience on working with Arduino Microcontroller. Meanwhile, He gets solid experience in Java and C++ programming. Software programming intelligence beside, he is also good at Solidworks and LabView. In Veroptimal, he will serve as CTO. His main task is design, build and test the software part of whole project.

### Tianye Zhou – Chief Financial Officer (CFO)

Tianye Zhou is a 4th year Electronic Engineering student at SFU. He specializes in software programming, digital hardware design, software and hardware debugging as well as test implementation. He had developed various skills including software programming, analog and digital hardware design, soldering along with hardware programming through 3 Co-op terms in three different areas. In addition, numerous mechanical design insights come from him, and his SolidWork skills contribute a lot to the spoiler system mechanical modeling. As a CFO in Veroptimal Solution, he takes care of the main part of the material and equipment purchasing.

# Conclusion

In this project, we want to build a rear spoiler of which its height and attack angle can be automatically or manually adjusted. For automatic, the spoiler system intakes the real timing feedback parameters such as car speed, downforce applied on the vehicle, road condition and even emergency events and then react correspondingly to optimize the aerodynamic performance of the vehicle. For manual, the users can arbitrarily adjust the spoiler through the control panel based on their preferences. Conclusively, by changing the traditional fixed-type spoiler to our Auto-adjustable Rear Vehicle Spoiler, the user can have better safety index and fuel economy and gain amusement by adding a personalized design on their car, and our goal for this design is to achieve the maximum utility that all a spoiler can provide.

The completion of our capstone project requires a combination of outstanding hardware designing, firmware programming, mechanical designing, circuit debugging, time management and teamwork. Therefore, this car spoiler project will be a huge learning and practicing challenge for our group members.

Technical work besides, we also need a great time management and effective workload distribution to achieve the goal. We have made a strict project timeline and a detailed project design plan to ensure we meet the deadline with a smooth and even development progress. The workload is also distributed to each team member base on their expertise and capability. Furthermore, we have two group meetings per week to summarize the current project progress and make a short term plan for the next week. What is more, we realize that we can learn very useful skills and gain new prospective from lecture hence we will absorb new methodology and knowledge about making a project into our existing project making plan.

# Reference


[1] Y. Xu. (2009, March 08). *Qi Che Feng Zu Shuo Ming* [Aerodynamics Analysis of Vechicles] [Online]. Available: http://designer.mech.yzu.edu.tw/articlesystem/article/compressedfile/(2009-03-08)%20%E6%B1%BD%E8%BB%8A%E9%A2%A8%E9%98%BB%E8%AA%AA%E5%88%86%E6%98%8E.aspx?ArchID=945.

[2] A. K. Mathews *et al.*(2014, June 02) *Study of Aerodynamic Effect Of Spoiler On A Car* [Online]. Available: http://www.slideshare.net/knightabyn/study-of-aerodynamic-effect-of-spoiler-on-a-car?related=6

[3] A. K. Mathews *et al.*(2014, June 02) *Study of Aerodynamic Effect Of Spoiler On A Car* [Online]. Available: http://www.slideshare.net/knightabyn/study-of-aerodynamic-effect-of-spoiler-on-a-car?related=6

[4] H. Yong and R. Chang, Lift and Drag Effects of a Rear Wing on a Passenger Vehicle, 1st ed. 1998.

[5] *Motor vehicle registrations, by province and territory (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick),* Statistics Canada, June 29, 2015.