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Master’s Dissertation 2014

Model-Based Design of a Co-Pilot for a Highly Automated Micro Electric Vehicle with Four In-Wheel Motors

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SUMMARY OF MASTER'S DISSERTATION

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Title

Model-Based Design of a Co-Pilot

for a Highly Automated Micro Electric Vehicle with Four In-Wheel Motors

Abstract

JSAE (Japanese Society of Automotive Engineers) and SICE (The Society of Instrument and Control Engineers) created a Benchmark Problem in order to design a new control system for increasing Micro EV-IWM's stability and safety. In addition, a report from US Department of Transportation is mentioning that most vehicle crashes happen because driver was watching other view instead of forward view, feeling tired or sleepy. Furthermore, a final report from European transportation consortium mentions about Highly Automated level in driving. In this level, driver is required to do less while driving, because there is a dedicated support that takes the driving control and does combination between lateral and longitudinal control.

In this research, driver is considered as one key factor in vehicle stability and safety control system. If driver is distracted or drowsy, Highly Automated level is considered to be useful for dealing with this critical situation. Therefore, this research is trying to design a Co-Pilot system in order to verify the stability or safety in Highly Automated Micro EV-IWM.

The processes of building Co-Pilot system starts from analyzing the proposed system in Vehicle-Driver-Environment (VDE) model, in order to get a brief explanation of the system's function. After that, the next process is using Model-Based Systems Engineering (MBSE) method for thorough analysis of the system. MBSE method delivers an abstract view of the system including functional view and physical view. In the last process, the proposed system is implemented inside the Benchmark Problem model. Using Dymola software, this modified model is simulated in the situation where the Micro EV-IWM facing a side winds, in order to verify its stability or safety.

In the result, Co-Pilot consists of many subsystems. It can judge driver state, take over the steering input, send alert signal, measure driver's respond, and restore steering input. These functions are considered sufficient to improve the safety in Micro EV-IWM. Based on the simulation result, the possibility time for Co-Pilot's to takes over steering input during crucial situation is very limited, just in a few seconds, and this possibility time is considered vital for developing a Co-Pilot system.

Key Word(5 words)
Co-Pilot, Highly Automated, Model-Based Systems Engineering, Distracted and Drowsy Driver, Micro EV-IWM

Contents

1. INTRODUCTION

1.1 Research Background

Global warming is now becoming world's concern. Many areas in the world facing climate change recently. For dealing with this issue, many countries are committed for reducing gas emission, the substance which is suspected as a trigger for climate change. Many governments are trying to endorse the implementation of non fuel vehicle in their transportation sector, e.g. Electric Vehicle (EV).

Along with the increase of technology and as a support for government policy towards global warming, most automotive companies are producing their own EV now. Many types of EV are now in the market. Based on EV's electric motor position, the early type of EV has its electric motor located under engine hood. Nowadays, another type of EV has its electric motor located inside the wheel rim and named as In-Wheel Motor (IWM) EV. In addition, based on EV's number of passenger, previous type of EV has at least four people. Recently, some auto companies produce smaller type of EV called Micro EV, where the number of the passenger is one or two people.

Within the combination of EV's type, some automotive research institutions are developing Micro EV with 4 In-Wheel Motor (Micro EV-IWM) as their next generation of EV. In the comparison with conventional cars, Micro EV-IWM has more flexible maneuver, however it has some issues regarding its handling and stability due to its lightweight. Therefore, JSAE (Japanese Society of Automotive Engineers) with SICE (The Society of Instrument and Control Engineers) created a Benchmark Problem in order to design a new control system for increasing Micro EV-IWM stability and safety. The Benchmark Problem is provided with some driving problems for many scholar and scientist to solve.

Discussion about vehicle stability and safety is also correlated with discussion about driving process. Based on Study Report for European Commission [**1**], there are three types of driving. The first type is Automated Driving. In this type, driving process is supported by a dedicated control which operates in continuous or a certain time operation, and with different support level, from low to high. The high support level is named as Highly Automated driving. In this support level, the dedicated control can over takes the driving process, however, human driver is allowed to gain a full driving control in anytime. The second type is Cooperative Driving. Generally for this type, the information and communication technologies (ICT) support the process of driving. ICT is transferring and analyzing a lot of information, in order to have a good and safe driving process. One benefit of using ICT is the option to swap information between vehicle and road infrastructure and also among vehicle itself. In this option, ICT can decide the best possible route for driver to follow. Finally, the last type is Autonomous Driving. Basically for this type, human driver is required to do nothing while driving, because all the process of driving is operated by a dedicated control in safe and reliable system. This type is considered as the ultimate type of driving.

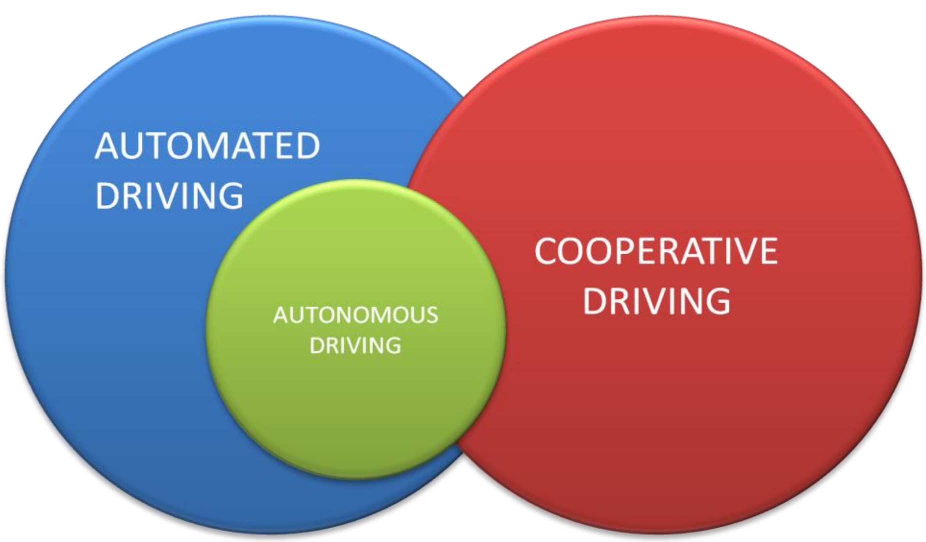


Fig. 1.1 Area and Overlapping in Three Types of Driving [**1**]

From Highly Automated Vehicles for Intelligent Transport (HAVEit) reference [**2**], there are levels of automation in driving. As shown in Fig. 1.2, the first level is Driver Only. In this level, driver is the person in charge who take care all driving process and without any artificial control involvement.

The second level is Driver Assisted, which consists of two sublevels for supporting the driver. First sublevel is Feedback sublevel, where driver receives some feedback input, such as sound, display and oscillation motion. Second sublevel is Support sublevel which delivers some actions to vehicle in firsthand in order to help vehicle elude obstacle e.g. braking input.

The third level is Semi Automated. Vehicle is equipped with more advance technology. A control device is built inside a vehicle for processing lateral or longitudinal control. One example of this level is Lane Keeping System, which maintain vehicle to stay between detected road lanes using steering assistance.

Later on, this fourth level is Highly Automated. In this level, driver is required to do less while driving, because there is a dedicated support that takes the driving control and does combination between lateral and longitudinal control. However, driver can retake the steering control in anytime, and after that the automation level will change to another level which depends on the driver's selection. It may change to Driver Only, Driver Assisted or Semi Automated.

The last level is Fully Automated. This level is actually similar with Autonomous Driving as mentioned above. In this level, driver is expected to sit still without delivering any effort for controlling the vehicle. An automation system will make sure that vehicle's cruising is underway in the safe and secure condition. However for some people, Fully Automated level is assumed to be undesirable, because for them, driver is the one who control the vehicle.

Furthermore, the Automation Level also consists of Failure State and Minimum Risk State. Minimum Risk State is defined as a critical condition where driver is not responding at all during driving process. To overcome this critical situation, the automation system will run a safely full stop procedure. The automation system will decrease vehicle's speed until it reaches a complete full stop and without harming other road users. In the Failure state, the automation system was considered not working properly, and even in the worst case situation, the automation system not works at all. This failure could happen because of component or application malfunction.

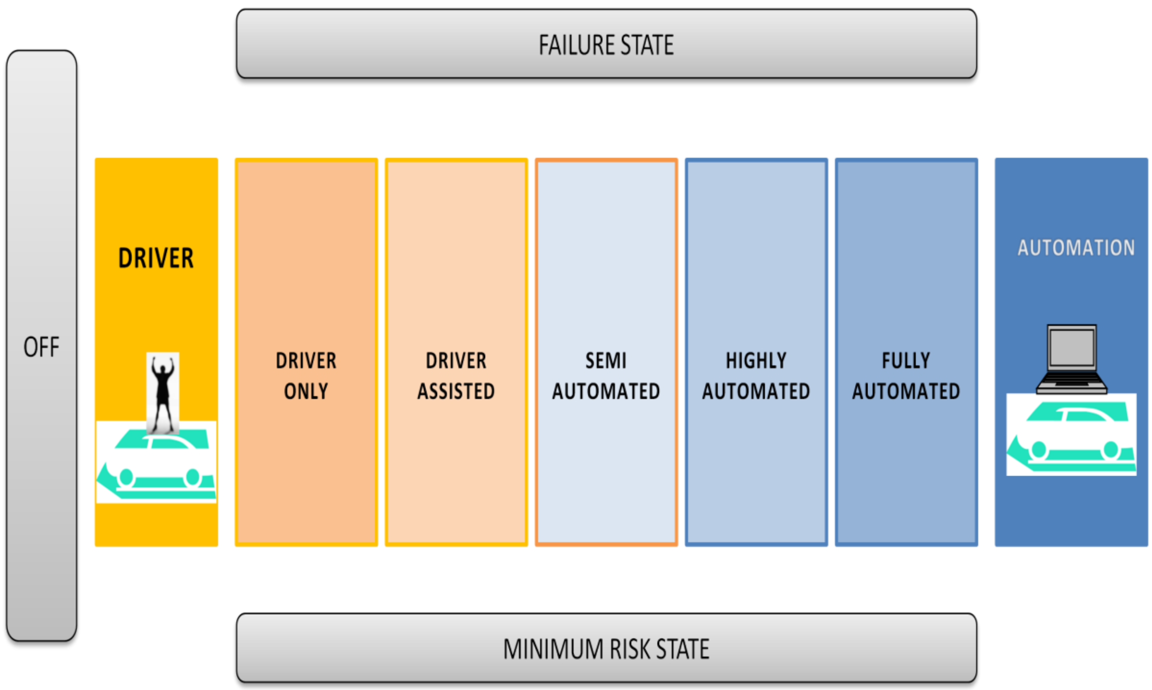


Fig. 1.2 Transition of Automation Level [**2**]

1.2 Research Problem

Discussion about driving level is also correlated with discussion about driver. Driver as the person who controls the vehicle and sets his/her vehicle to the intended direction or speed, always expecting no accidents or problems will occur. Driver will behave carefully and act according to traffic law. Driver also tries to prevent unwanted occasion such as leaving the road lane or hit a vehicle in the front. Additionally, driver must maintain visual contact to the front road, and check regularly the rearview mirror, in order to detect any possible obstacle, hazard and blind spot. Driver, as much as possible, will avoid doing secondary task of driving, a task that is not related to driving task. This secondary task can cause distraction or losing attention for driver, e.g. talking on the cell phone or eating. In principle, driver tries to prevent themselves as a triggered that caused danger or accident for all road users.

However, based on National Highway Traffic Safety Administration (NHTSA) of US Department of Transportation's report [**3**], researcher found that driver who distracted and watched other view instead of forward view is responsible to approximately 80 percent of all crashes and 65 percent of all near-crashes. Later on the report said that 12 percent of all crashes and 10 percent of all near-crashes were happen because the driver felt sleepy or drowsy. Those numbers are much higher compare to most current database for drowsiness. Researcher also found that in many accidents, drivers were actually very tired, ready to fall asleep at any time, incompetent to take decision, performed secondary tasks, fierce while driving, and disobey traffic rules.

In addition, many automakers are now using a vehicle stability control in their carrier. Fuller in her research [**4**] tries to deliver a brief explanation about this type of control. Mainly, there are two ways to control the vehicle. Lateral Control is achieved by utilizing the steering wheel and Longitudinal Control is acquired by utilizing the gas and brake pedals. However, at this point, this controller does not check the driver status, whether the driver is distracted, drowsy or in full awareness, even though as mentioned before, lacking of driver's attention in driving can trigger an unfortunate event.

Based on the description above, there is always a chance for driver to misbehave while driving and this can lead to injury and accident. Therefore, this research is trying to propose a control system that monitor driver condition and assist driver when the situation is needed. Driver is considered as one key factor in vehicle stability and safety control system. If driver is distracted or drowsy, the automation level is considered to be useful for dealing with this critical situation.

However, there are several research questions that arise regarding to this proposed control system. The list of the questions are "how to detect distracted or drowsy driver?", "what will happen if the proposed control system detects distracted or drowsy driver?", "how to evaluate the proposed control system and what is the system's criteria of success?", and "how to define interaction between the proposed system with the driver". In order to answer those questions, this research use model based system engineering method for building the concept of the proposed control system, and after that, the proposed system is tested and analyzed by Dymola simulation software using Benchmark Problem simulation model.

1.3 Research Purpose

In the automotive world, vehicle stability control has been proven to become an effective device for making the vehicle more stable and safe, however this device merely detects vehicle's dynamic. Also, by considering the consequences of distracted or drowsy driver for Micro EV-IWM's stability and safety performance, this research consider to build a support system for overcoming the driver's problem. This research puts the driver factor as concern area for building a new system which can ensure driving performance stability and safety.

There are several considerations for building the support system which called Co-Pilot system. In the first consideration, Co-Pilot is activated by the driver only. Driver is the initiator who activates or deactivates Co-Pilot system. After engine start, Co-Pilot is still inactive, and it needs driver's action for turn it on. Furthermore, Co-Pilot system is supported by electricity power from vehicle, so whenever the engine is off, Co-Pilot system is also deactivate consequently. Also, Co-Pilot is designed to monitor driver continuously and in some particular situation, Co-Pilot receives a privilege to overtake driver's command. However, during overtaking period, if driver insists to deliver any driving input, Co-Pilot will analyze and calculate the situation based on one rule, safety is the first priority. Because of this, Co-Pilot has the authority to refuse driver's command if the result will lead to danger or accident.

Next consideration, the privilege for artificial device to control vehicle is actually the same privilege in automation system of Highly Automated and Fully Automated Level. Therefore, Co-Pilot's position in Type of Driving and Automation Level is considered as highly automated level. In conclusion, the objective of this research is to design a Co-Pilot system in order to verify the stability or safety of vehicle in Highly Automated Micro EV with four In-Wheel Motors.

1.4 Structure of Thesis

This paper consists of five chapters. Research's background, problem, and purpose are delivered in Chapter One. For Chapter Two, the description is about processes of designing Co-Pilot system in the perspective of Vehicle-Driver-Environment (VDE) Model and Model Based System Engineering (MBSE) method. There is also a validation process using a questionnaire. This questionnaire is to validate Co-Pilot system concept and reasons for building this Co-Pilot system.

Next in Chapter Three, the Co-Pilot concept is tested by Dymola simulation software in Benchmark Problem model, where the type of vehicle for simulation is Micro EV-IWM only. There are several assumptions for modeling a distracted or drowsy driver in this simulation. Driver has no input, driver has a delayed input, driver has an offset input, and driver has an offset with a delayed input are actually assumptions for describing distracted or drowsy driver.

Chapter Four is discussing about the simulation results. The indicator to measure driver state, the device to measure it, and parameter for simulation are described by this chapter. The further discussion is about the relationship between alert signal and expected respond, and the possible time for Co-Pilot's to taking over which based on the simulation result. Finally in Chapter Five, the results are being recap once again, including some of the limitations and difficulties in this research.

2. CONCEPT DESIGN OF CO-PILOT

2.1 Co-Pilot Concepts in Vehicle-Driver-Environment (VDE) Model

The interaction between driver and vehicle is considered as one of the major focus for many auto makers. This interaction can be seen in the vehicle-driver-environment (VDE) model of Fig. 2.1. Reñski in his paper [**5**] describes VDE in more detail for each of the model components and Fig. 2.2 is showing a diagram of the driver model.

In terms of vehicle, vehicle is consisting of thousand of physical parts and it has a function for transporting people or goods on the land. Vehicle is designed to comply with driver's input, such as steering, accelerating and breaking. Moreover, due to vehicle interaction with environment and to the condition that vehicle simultaneously accepting driver's input, vehicle will create a respond as the resultant of that two reasons. Usually, vehicle respond is seen as vehicle state of motion (vehicle dynamics), and the example of vehicle state of motion are lateral displacement, yaw angle, vibration, etc. Regarding of driver, driver as the person who control and drive vehicle, is also concurrently processes all information which come from environment and vehicle. The way for driver accepted the information is using driver's perception and valuation. The name of perception and valuation are actually an image of human natural senses and brain work. Moreover, driver is expected to produce some action or decision in the term of driver's input. In addition, before starting to drive, drivers are also considered to have their own initial desired that consist of desired speed and desired path. These initials desired may also come from vehicle passenger, as a person who ask driver to direct the vehicle in to specific destination and specific speed. As for environment, driver and vehicle are influenced by external factors such as road condition, unexpected disturbance, traffic regulation, or weather. These factors may vary depends on location and time.

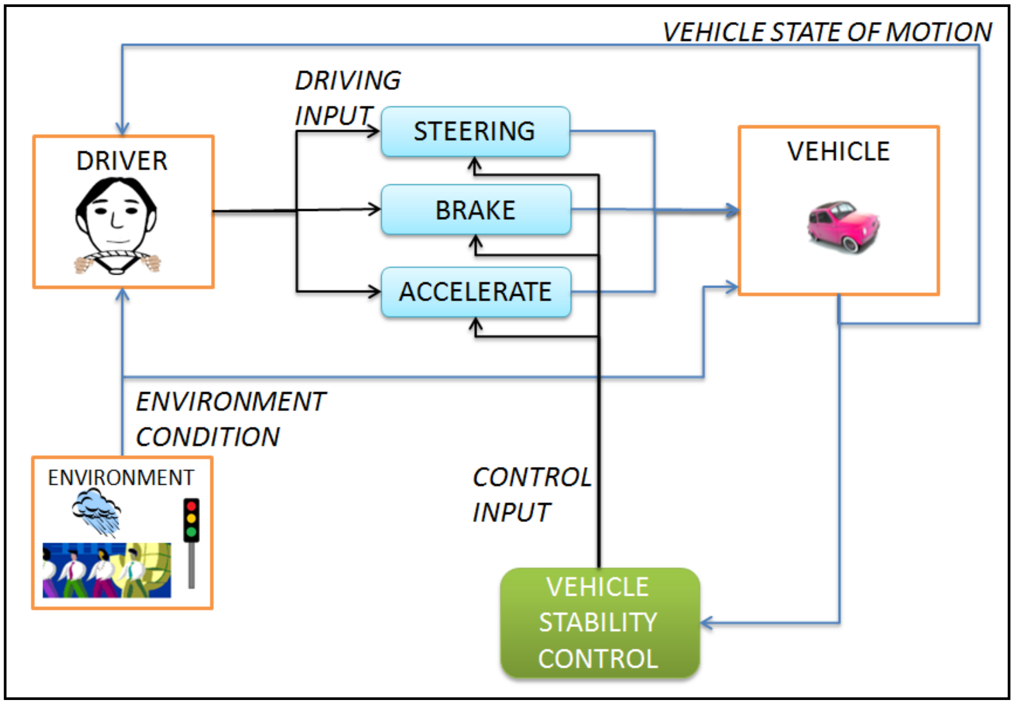


Fig 2.1 Diagram of Vehicle-Driver-Environment (VDE) Model

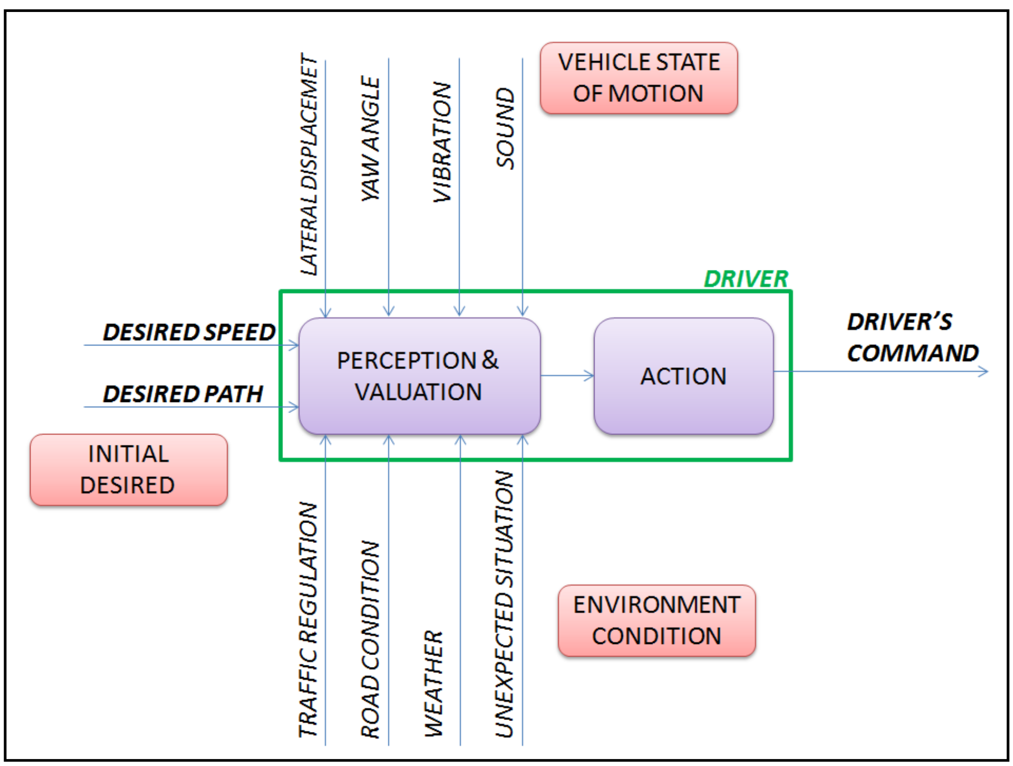


Fig 2.2 Diagram of Driver Model

As mention in research problem, driver has a big impact that dealing with accident, even though the vehicle is equipped with VSC. Therefore, this research tries to design a Co-Pilot system which can monitor the driver state continuously. In addition, Co-Pilot system will also capable to monitor vehicle state and environment condition. The monitoring abilities are considered to be the same monitoring functions in human driver. However, because Co-Pilot is an artificial system, the process to monitor the surrounding will use many devices and tools such as camera or sensor. In VDE Model, the position of Co-Pilot system is actually located inside vehicle. It has a routine function to monitor VDE, as seen in Fig. 2.3.a. The Co-Pilot system is actually duplicating the driver. However, if Co-Pilot detects that driver is incapable for driving task (Driver is assumed NOT OK), this system has an authority to run some functions that will support driver for the sake of driver safety. The functions consists of block driver's input, overtake driving command, and alert driver for driver to regain full awareness. In the block driver's input function, all driver input that goes to vehicle is ignored by vehicle, because Co-Pilot switches the source of driving command from driver to Co-Pilot. After that, Co-Pilot will overtake the driving command as its second function. The only affected driving command comes from Co-Pilot only. Co-Pilot decides all routes for vehicle to cruise. While doing the second function, Co-Pilot will try to alert driver by sending many sound, voice, vibration or display in the hope that driver can regain his or her awareness including awaking the driver. If driver can retrieve self awareness, which means that the Co-Pilot assumes that driver is okay, the control input will goes back to driver and Co-Pilot will back to do idle operation for monitoring. However, in the worst case scenario, driver may not respond any alerting signals. Therefore, Co-Pilot will run emergency safety full stop operation. Co-Pilot will reduce vehicle speed until complete full stop in the nearest possible place for vehicle to park and without harming anyone.

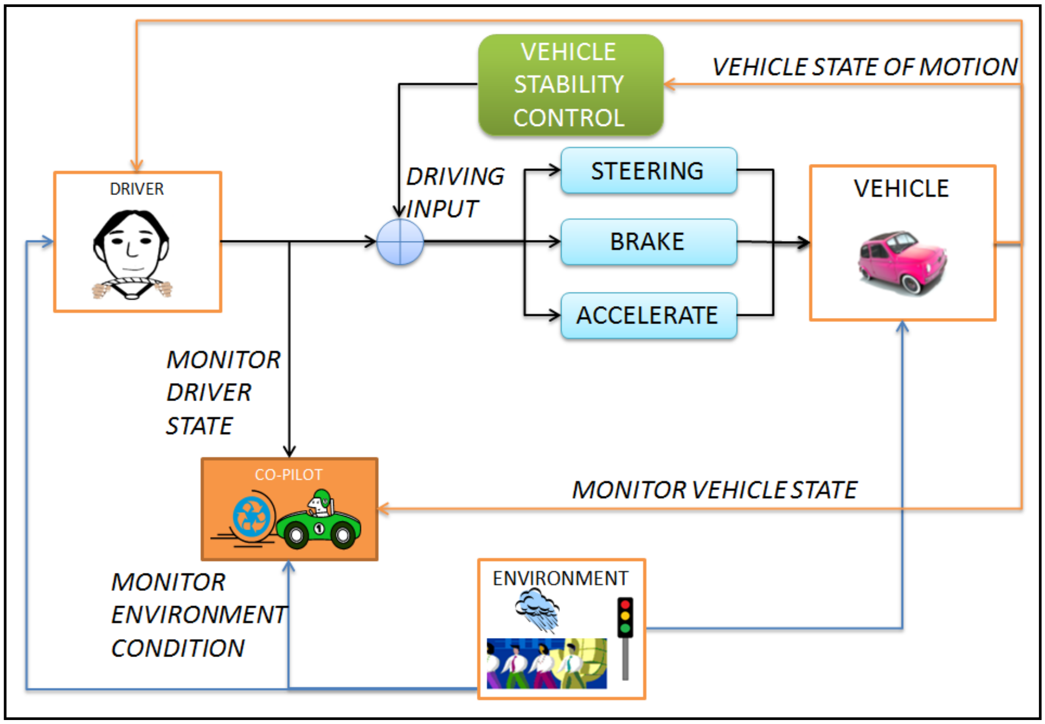


Fig 2.3.a VDE Model with a Co-Pilot while Driver is assumed OK

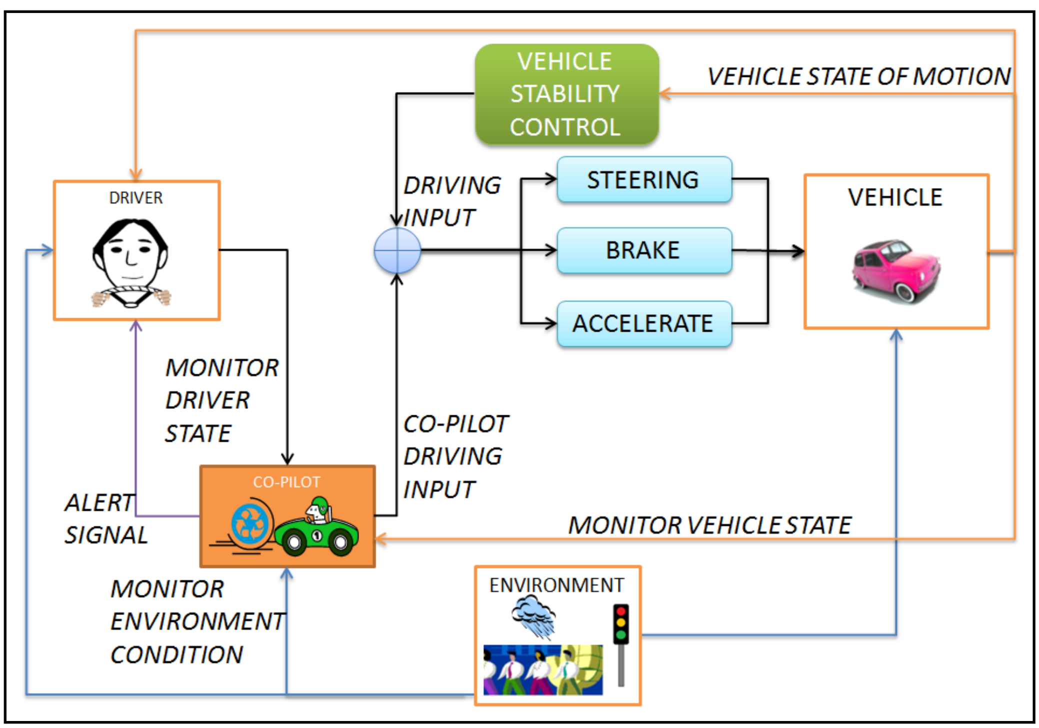


Fig 2.3.b VDE Model with Co-Pilot while Driver is assumed NOT OK

In further analysis, Co-Pilot is designed to behave as an ordinary driver. It can sense the vehicle, detects surrounding and delivers driving output. In other word, Co-Pilot will have the same functional process as in human driver. Duplicating the same component in Fig. 2.2, Co-Pilot has components consists of Data Receiver, Assessment and Action subsystems. In Fig 2.4, Data Receiver and Assessment subsystems are acting as same as Perception and Valuation in a driver. Meanwhile, Acting Subsystem is not only to sends driver input to vehicle, it is also delivering alert signals in to driver in order to waking up the driver.

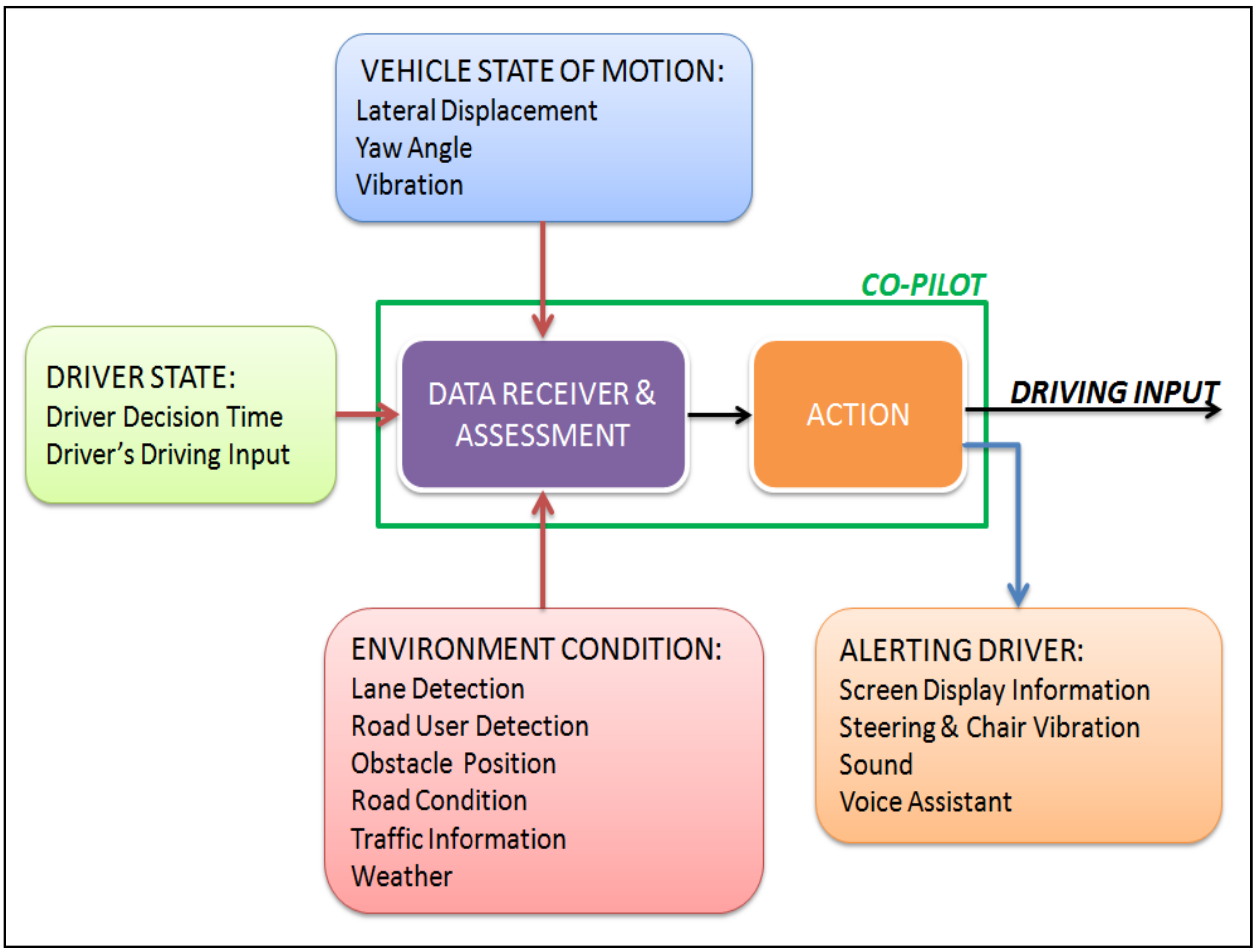


Fig 2.4 Diagram of Co-Pilot Model

2.2 Co-Pilot Concept in Model Based System Engineering (MBSE)

Model Based System Engineering (MBSE) is one method in System Engineering for describing a system using system model. MBSE provides an abstract view of the system which is useful for analyzing the system prior building real system. Moreover, MBSE is not limited to some mathematics equation and it can bring various points of system's view e.g. Structure Diagram and Sequence Diagram. A system's description using MBSE is useful for next process in analytic process e.g. computer simulation.

From the SysMl reference book [**6**], there are diagrams that useful for describing a system. Requirement Diagram (req) is useful for mentioning all requirement or specification of the Co-Pilot system. Use Case Diagram (uc), Sequence Diagram (sd), State Machine Diagram (stm), and Activity Diagram (act) are usable for describing Co-Pilot's behavior. Meanwhile, Block Definition Diagram (bdd) and Internal Block Diagram (ibd) are for portraying Co-Pilot's structure.

In the beginning of analyzing Co-Pilot system, the initial requirement for Co-Pilot system has to be set up first. These requirements are stating capability of a designed system that must be satisfied. Basically, Co-Pilot's requirement is to make sure the sake of driver safety. Co-Pilot shall monitor environment condition, vehicle state and driver state. Thus, Co-Pilot shall support driver at the moment when the system detects that driver is incompetent to drive the vehicle. As shown in Fig. 2.5, the Co-Pilot requirement block consists of three sub requirements. In first part, "Monitoring Situation" consists of "Monitoring Driver State", "Monitoring Environment Condition", and "Monitoring Vehicle State". Co-Pilot has the monitoring condition as its idle operation for checking driver, vehicle and environment. The monitored process is conducted in parallel and continuous process.

In monitor the driver state, Co-Pilot system has the capability to decide driver state condition using certain criteria. In this checking process, Co-Pilot system has to judge whether driver in good awareness or not. Also, in monitor the environment condition, Co-Pilot system has to detect objects position surrounding the vehicle, weather condition, traffic sign and other things including traffic congestion and street walkers. Later, in monitor the vehicle state, Co-Pilot system has to measure and calculate vehicle dynamic parameter, as yaw rate, roll rate, and pitch rate and other parameter, for instance slip angle, motor torque and steering wheel input.

In next requirement block called "Assisting Driver", this block consists of "Alerting Driver", "Overtaking Vehicle Control", and "Emergency Stop". In general, this particular requirement and its sub-requirements are for describing Co-Pilot ability for helping driver during critical situation, a situation where driver is considered to be incompetent for handling and controlling the vehicle. In critical situation, driver is in distracted or drowsy condition. Therefore, Co-Pilot has to perform actions for preventing driver from life-threatening situation.

In alerting driver, Co-Pilot system is capable for sending signals, vibration and sound to wake up drowsy driver or to alert distracted driver. Also, in overtaking vehicle control, Co-Pilot is granted with one function for delivering acceleration, braking and steering wheel inputs into vehicle, because driver is distracted or drowsy. Later, in emergency stop, Co-Pilot system has ability for decreasing vehicle speed into safety full stop condition because driver is not responding to alert signal at all.

The third requirement block is "Working Environment Constraint". This requirement is actually defining the scope and working boundary of the Co-Pilot system. As written in the block, Co-Pilot system shall be capable for assisting driver, monitoring vehicle, and identifying environment under all normal weather, traffic and terrain condition.

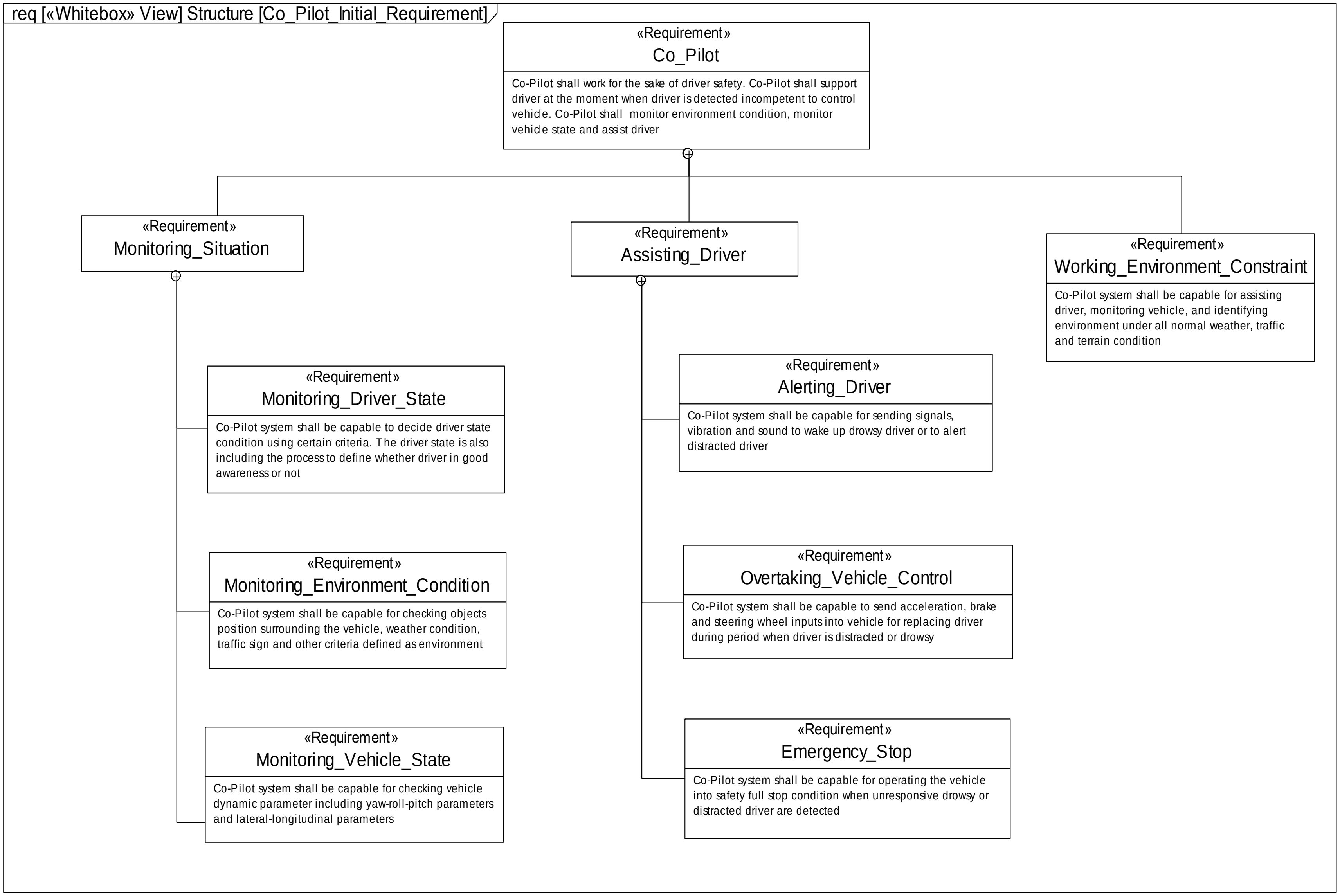


Fig. 2.5 Initial Requirement for Co-Pilot System

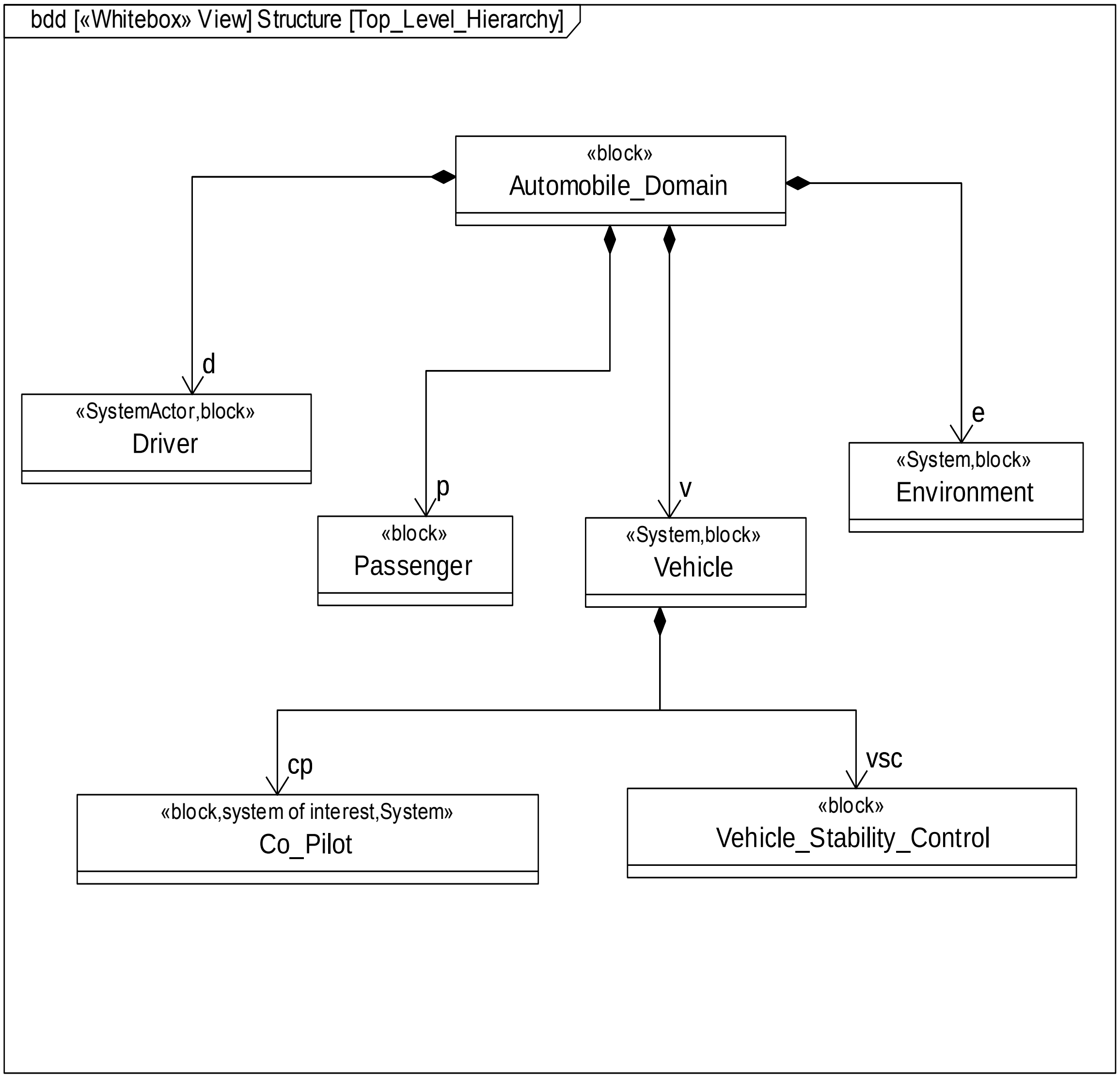


Fig. 2.6 Block Definition Diagram of Automobile Domain

The block definition diagram in Fig. 2.6 shows a structure of Automobile Domain in the top level hierarchy. It has been decompose in to several blocks. They are driver, passenger, vehicle, and environment blocks. Driver and passenger blocks are actually the vehicle occupant, and environment block is the surrounding object or entities such as road, road user, atmosphere condition, traffic sign etc. Vehicle block is a system like an automobile that has functional properties to move, accelerate, decelerate, and also turn. The vehicle block consists of Vehicle

Stability Control (VSC) and Co-Pilot system. There are some example of VSC, such as Anti-lock Braking System (ABS) and Electronic Stability Programs (ESP). Later on, this paper is going to discussing and analyzing the Co-Pilot system, as the system of interest, in more detail.

After deciding Co-Pilot as the system's interest, the next step is to describe the components inside the system of Co-Pilot domain. In Fig. 2.7, the block definition diagram is mentioning Co-Pilot Domain and its related blocks. As same in Automobile Domain, driver, vehicle and environment blocks are also included in Co-Pilot Domain, however in this domain, VSP is assumed to be united inside vehicle blocks and Co-Pilot is put in a separated block. The reason to include vehicle, environment and driver in Co-Pilot domain are actually based on the requirement of Co-Pilot itself. As mention before, Co-Pilot's scope of work are to monitor surrounding, vehicle dynamic parameter, and the person who control vehicle, and this is also including assisting him/her in a certain critical situation.

Next process, one method for seeing the behavior of Co-Pilot is by using a use case diagram. As shown in Fig. 2.8, Co-Pilot provides some functions that will be used by external system or system actor. The name of the use case in this figure is actually clear and obvious for defining the correlated external system. "Identifying Environment Condition" is connected to environment, and "Monitor Vehicle State" is linked to vehicle. Vehicle also connects to "Assist Driver". Driver has connection with two use cases, "Monitor Driver State" and "Assist Driver". In assist driver, the reason this use case has connection to driver and vehicle is that during assisting driver period, Co-Pilot system has to do parallel process simultaneously, such as alerting the driver and also overtaking the driving command. In addition, these use cases are still in the upper level of system's behavior and it needs to be decomposed in to lower level use case.

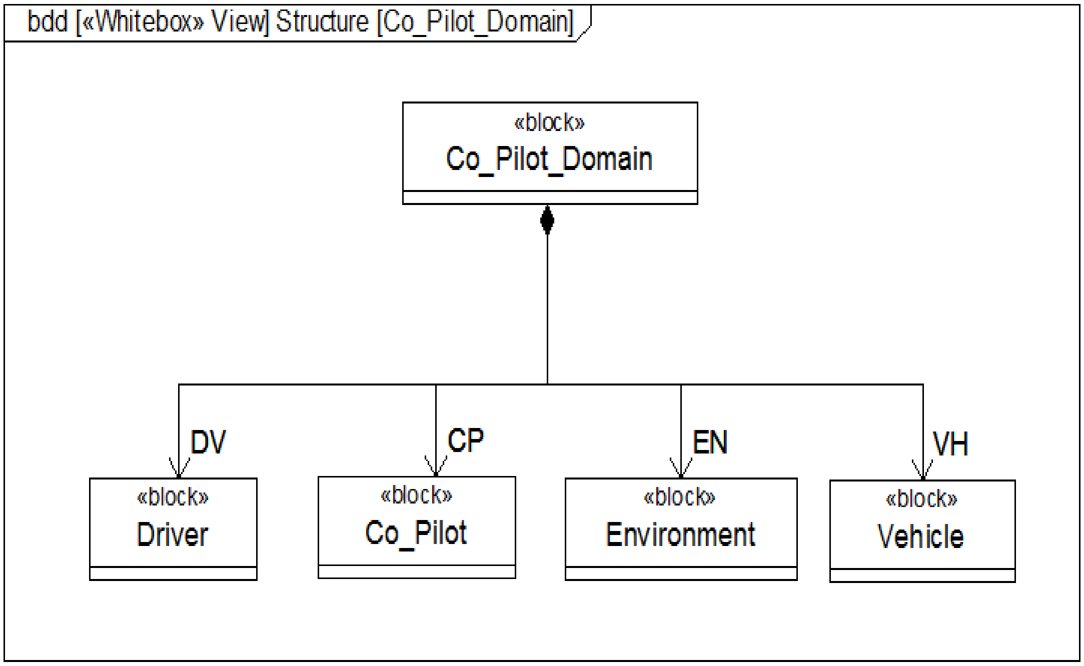


Fig. 2.7 Block Definition Diagram of Co-Pilot Domain

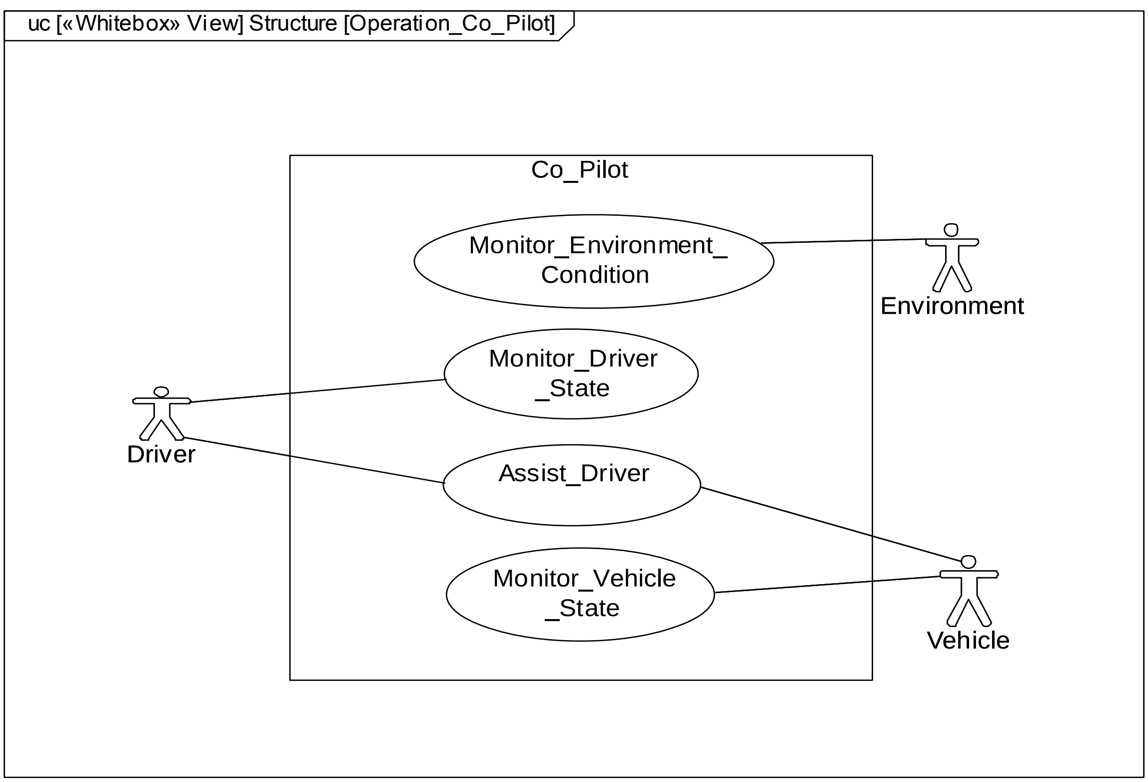


Fig.2.8 Top Level Use Case Diagram of Co-Pilot Domain

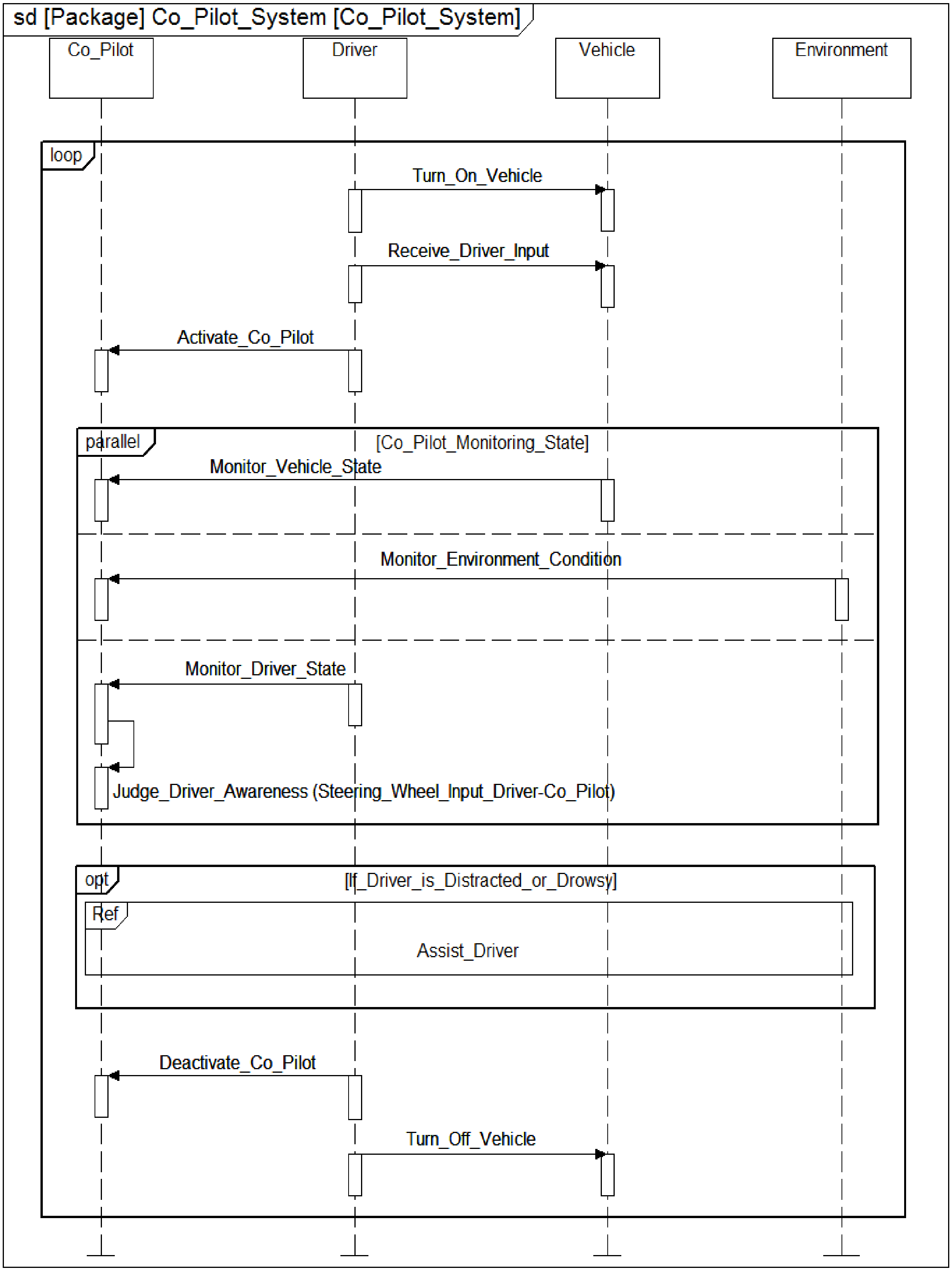


Fig. 2.9 Sequence Diagram in Co-Pilot System

Sequence diagram is also useful for seeing the behavior inside Co-Pilot domain. Fig. 2.9 is depicting behavior between Co-Pilot and its related system using exchanging message. In this diagram, “Turn on Vehicle” and “Receive Driver Input” messages are sent from driver to vehicle to vehicle, before sent “Activate Co-Pilot” message to Co-Pilot.

When Co-Pilot is active, there are three parallel messages occur. First message is named as “Monitor Vehicle State” where Co-Pilot runs a function such as measuring vehicle dynamic and detecting vehicle position. The second message is “Monitor Environment Condition”. In this process, Co-Pilot is conducting some functions such as detecting road condition, detecting road user, and estimate traffic congestion. Last processes are “Monitor Driver State” and “Judge Driver Awareness”. Driver behavior and driver awareness is being watched by Co-Pilot, and after that, Co-Pilot will analyze the result for determine the driver awareness, incompetent for driving or not.

In the message line, the way to determine driver awareness is described in the argument bracket. Comparing steering wheel input between driver and Co-Pilot is the method for judging the awareness level. Based on this, this message line is actually can be described in detail, because before comparing, Co-Pilot should define its steering wheel input where driver steering input is come from monitoring driver state. Therefore, judging function is actually may consist of many processes inside.

Moreover, in “opt” box named as “Assist Driver”, there is a reference interaction that will describe later in more detail. This reference is present only in condition when driver is assumed in distracted or drowsy situation. If driver is assumed in normal condition, the sequence goes to “Deactivate Co-Pilot” message prior to “Turn off Vehicle” message.

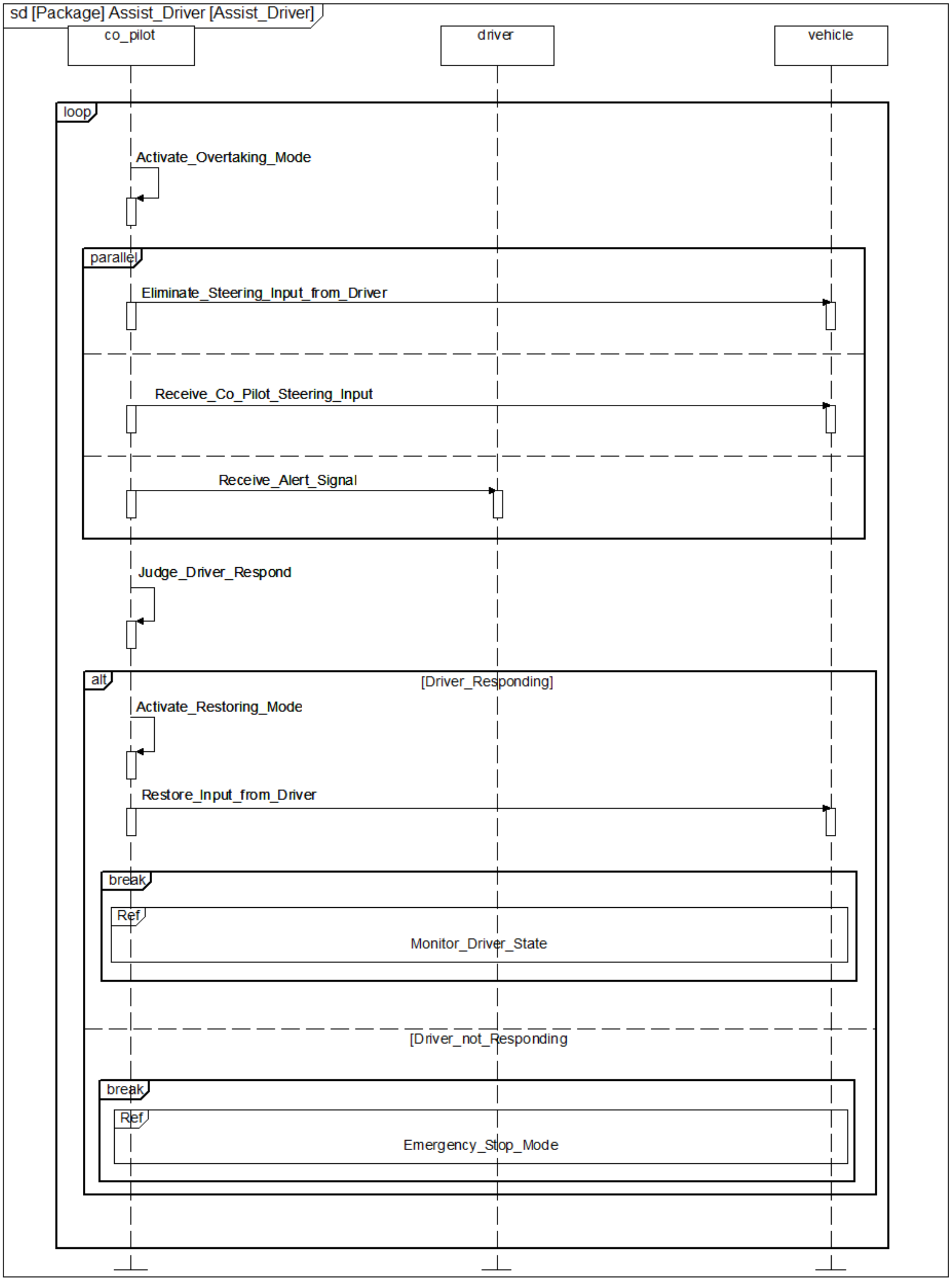


Fig. 2.10 Sequence Diagram in Assisting Driver

Fig. 2.10 is trying to give detailed explanation of what is happen inside the “Assist Driver” reference point as mention in Fig. 2.9. At first, Co-Pilot is doing “Activate Overtaking Mode” function and it will followed by three parallel messages. “Eliminate Steering Input from Driver” and “Receive Co-Pilot Steering Input” messages go from Co-Pilot to vehicle. In this process, vehicle only receives steering input from Co-Pilot and not from driver, because it is assumed that somehow, vehicle has a switching device for determining its steering input source. The third message is “Receive Alert Signal” that sent by Co-Pilot to driver. The alert signal may be in the form of sound, vibration and voice mode. The purpose for sending this kind of awaken format is to help driver to focus and regain awareness.

Next step, Co-Pilot is evaluating driver reaction in the form of “Judge Driver Respond”. In this function, the system does checking and analysis based on driver’s eye movement, head direction and steering input. Other idea for this function that driver is obliged to answer Co-Pilot question in one monitor display. The answers can be in the form of touch some screen button or voice reply. At the end, the outcome is divided in two possible conclusions.

First conclusion is in the form of driver is responding. If this happen, Co-Pilot runs an “Activate Restoring Mode” message that consists of two actions, stop sending Co-Pilot steering input to vehicle and stop sending alert signal to driver. In here, Co-Pilot is cutting off the overtaking input and awaking signal. Later on, “Restore Input from Driver” message is sent by Co-Pilot to vehicle where the switching device will go back to its original source, driver steering input. At this moment, driver is in full control of vehicle and Co-Pilot is return to its first process which is monitoring driver.

The second conclusion is in the form of driver is not responding. This situation is not preferred by Co-Pilot system because it is a life-threatening situation. Based on that, Co-Pilot is performing “Emergency Stop Mode” reference which consists of stop vehicle speed in safe process, turn off vehicle power, and deactivate Co-Pilot. In this condition, Co-Pilot has no other option than to parking the vehicle in the nearest location until driver is recovering from drowsy situation. After that, Co-Pilot sends a turn off vehicle message which is also means that Co-Pilot is doing self-termination function. The lower level sequence diagram of emergency stop reference can be seen in Fig. 2.11.

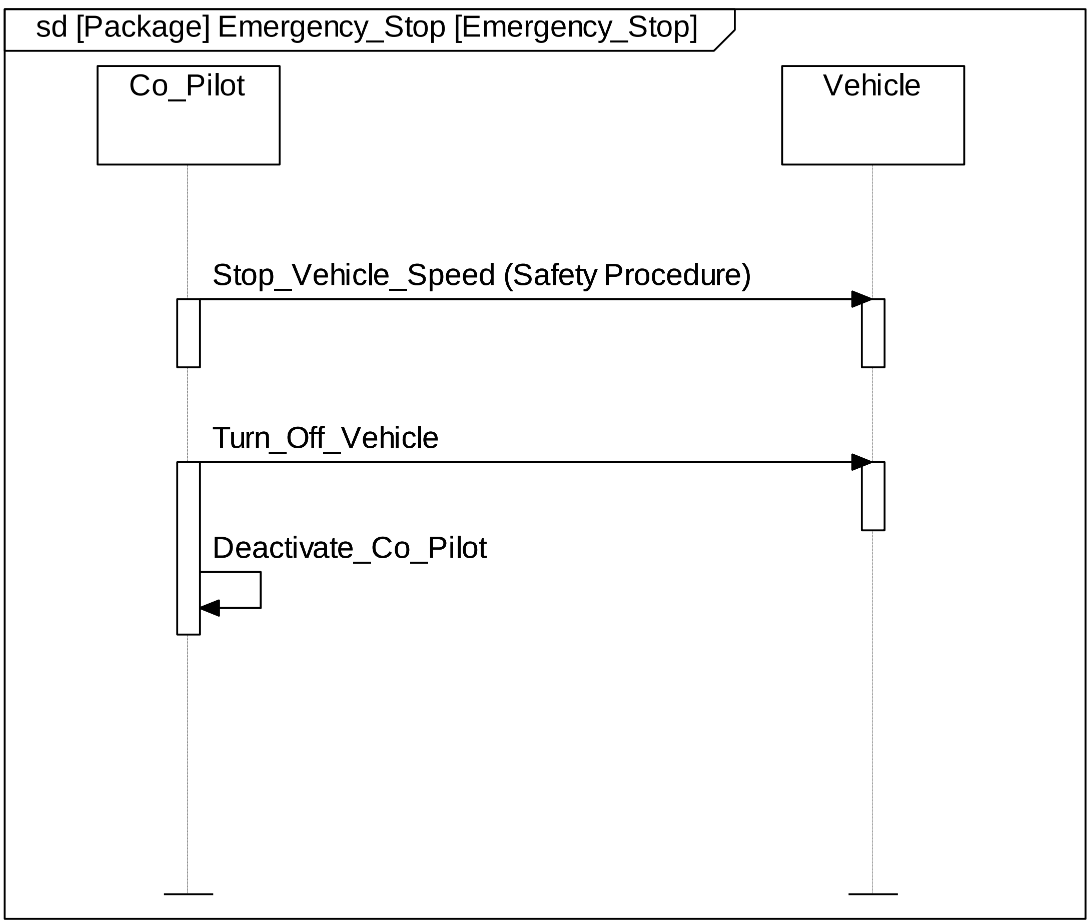


Fig. 2.11 Sequence Diagram of Emergency Stop

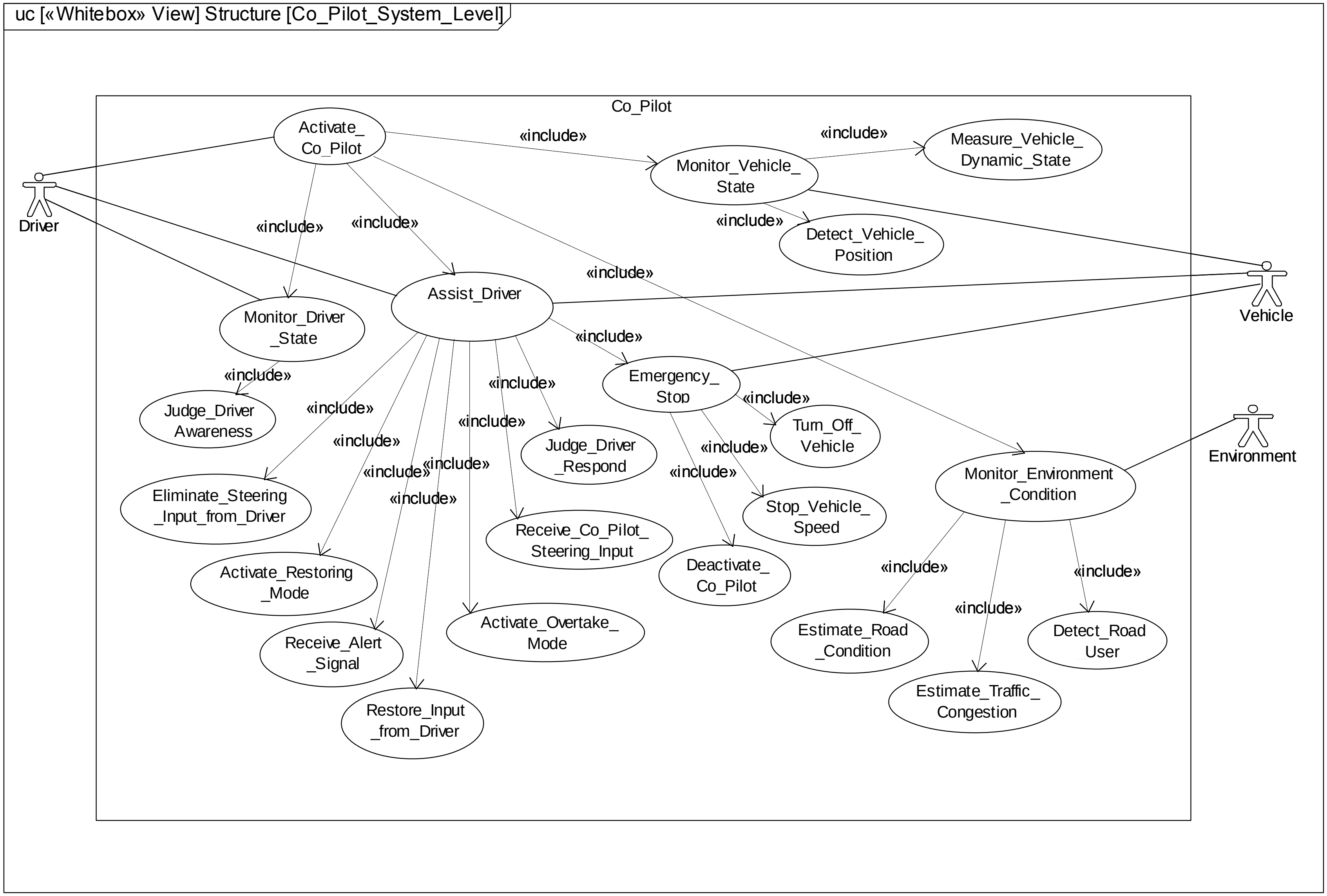


Fig. 2.12 Decomposition Use Case in Co-Pilot System

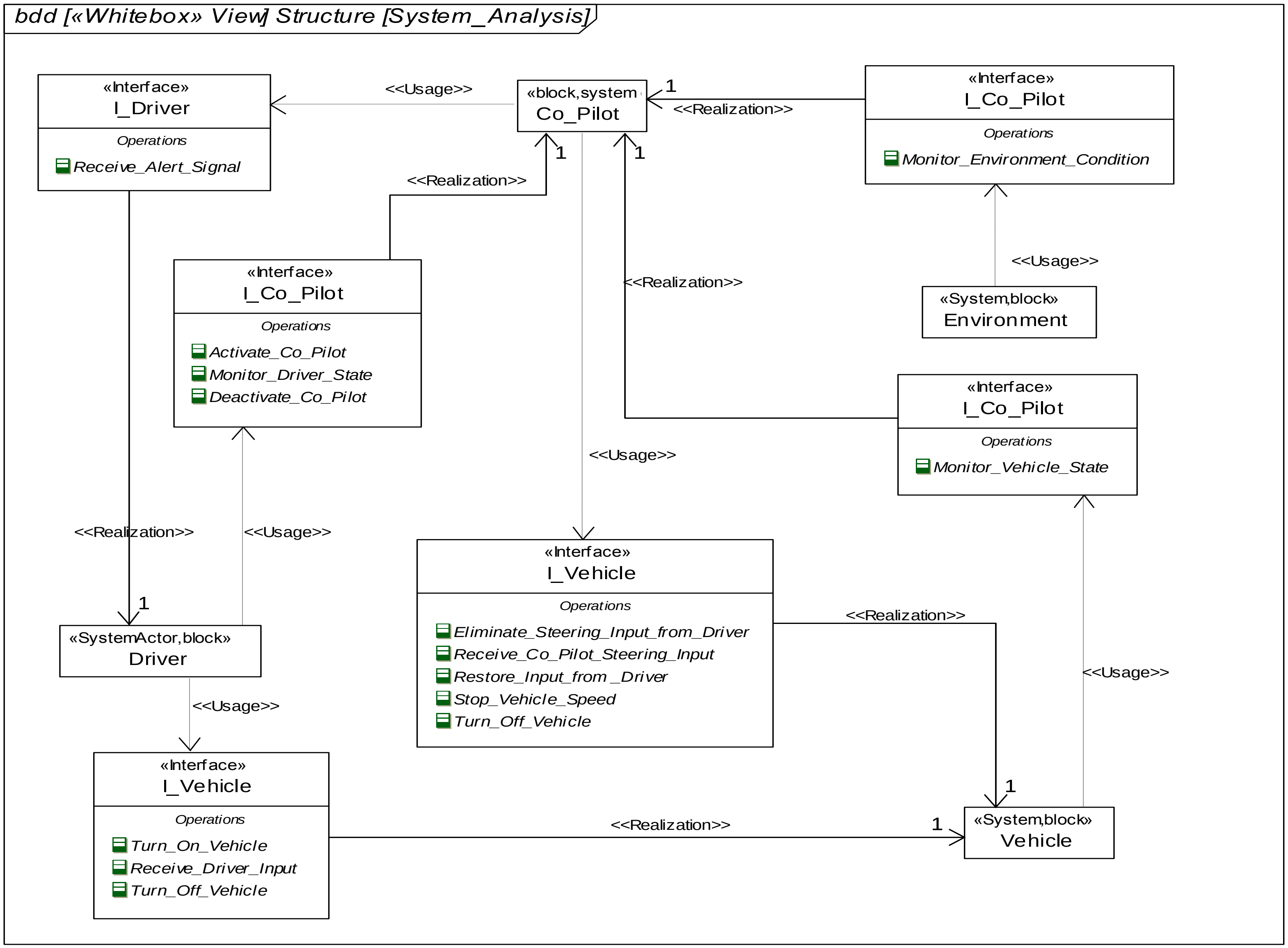


Fig. 2.13 Block Definition Diagram of Interfaces between Co-Pilot and External System

Co-Pilot's behavior in terms of its transitions between states that triggered by events, are shown in state machine diagram of Fig. 2.14. At beginning, Co-Pilot will be in "Co-Pilot off" state. The "activate CP" event will trigger a state's transition and therefore the new state will appear. Once the state in "Co-Pilot on", it will immediately change to "Monitoring" state. In this state, do behavior is performing actions called check for driver state, vehicle state, and environment condition. In addition, the transition state from "Co-Pilot on" to "Co-Pilot off" could be fulfill if the "deactivate CP" event is exist.

If "driver is drowsy or distracted" event is appeared, new state transition will occur and the state will become "Assisting Driver" state. This state is a composite state, with regions for "input to vehicle" and "input to driver". In "Co-Pilot Driving" state, the do behavior are eliminate driver steering input and send Co-Plot steering input to vehicle. Next in "Alerting Driver" state, the do behavior will send wake up signal including sound, vibration, and display to driver.

From composite state, the process will be determined in two events as the trigger for different state transition. If the event is "driver is responded", the state will become "Restoring Driver Input" state, and the do behavior of this state are consist of restore driver input, stop send Co-Pilot steering input and stop alerting driver. After that, the state will change once more and it goes back to the previous condition, in the "Monitoring" state. This process is becoming a loop in state transition. However, if "no response from driver" event is occurred, the state will change in to "Emergency" and do behavior is carrying out actions which consist of safety full stop of vehicle, turn off engine, and shut off Co-Pilot. In this state, the transition will reach final node with description that engine is off and it is also means that Co-Pilot is off. This last process is the end of state transition.

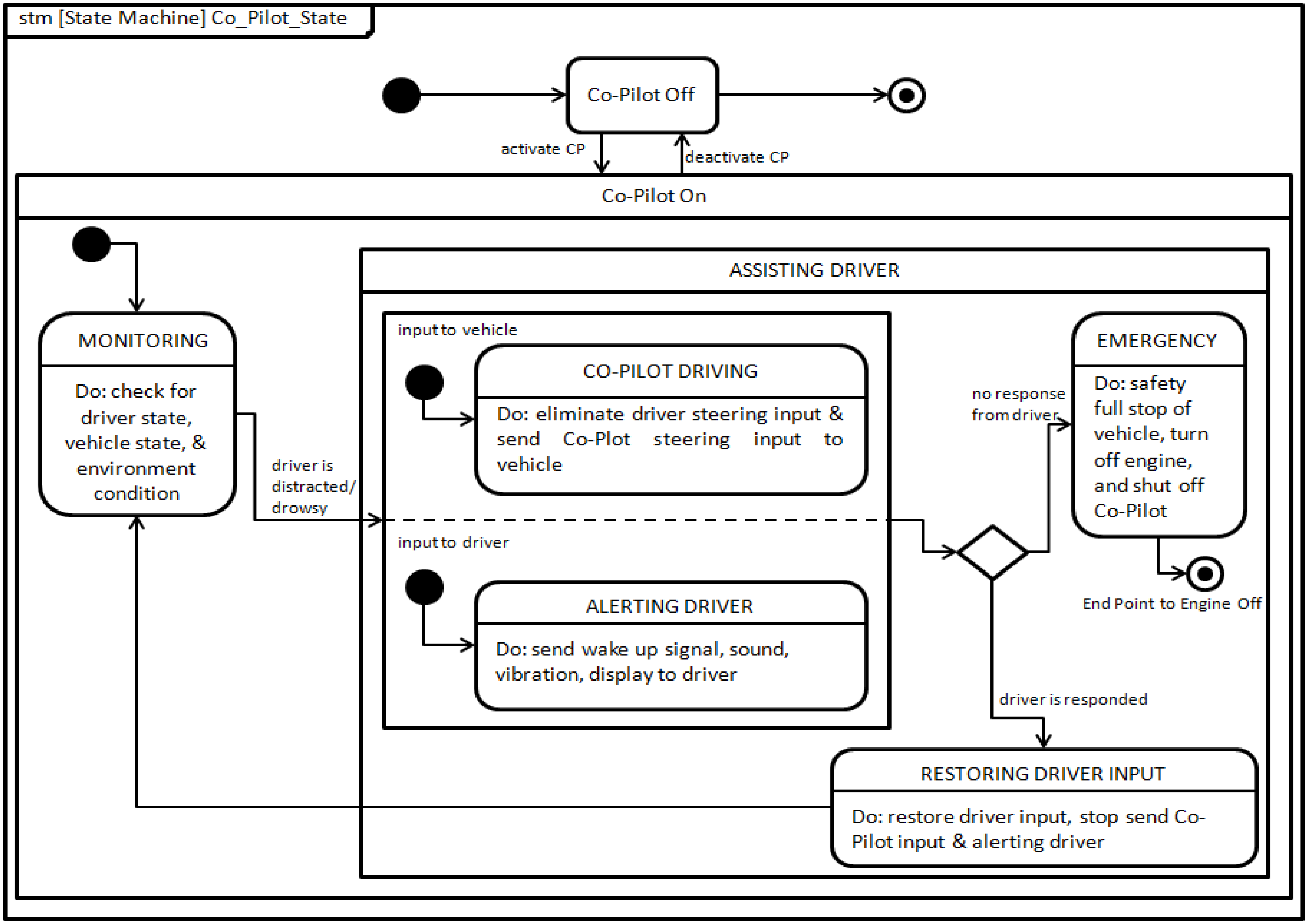


Fig. 2.14 State Machine Diagram of Co-Pilot

A lower level structure of Co-Pilot composition is shown in block definition diagram in Fig. 2.15. There are three block components inside Co-Pilot. They are "Data Receiver", "Assessment", and "Action" blocks. On its function, "Data Receiver" will retrieve all the necessary information which may come from driver, vehicle or environment. Based on the reference [**1,2**], there are many devices or equipment that can be used to retrieve the information from surroundings, such as camera, ultrasonic device, infrared device, accelerometers, gyro sensors, wheel speed sensors, etc. All information from first block will be further analyzed in the "Assessment" block. This block is all about what decision to do next. The decision to judge driver awareness, activate overtaking mode, judge driver respond and activate restoring mode are given in this block. Next block is "Action" where execution process is being done in this block which consist of eliminate steering input from driver, send co pilot steering input, send alert signal, restore input from driver, and also doing emergency stop.

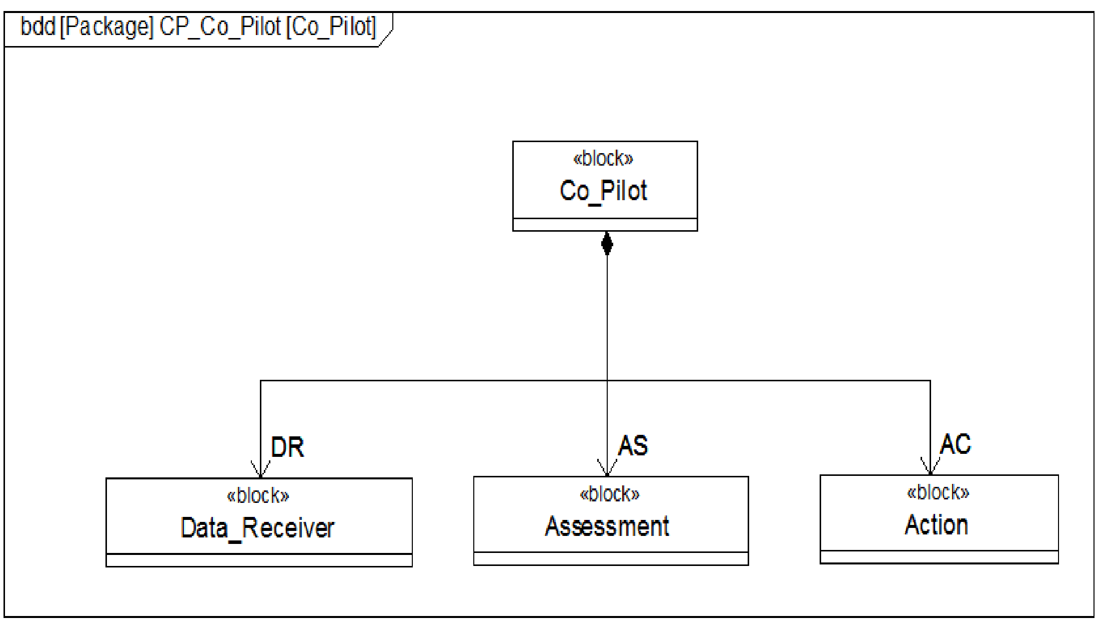


Fig. 2.15 Block Definition Diagram of Co-Pilot Subsystem

Table 2.1 Diagram of Co-Pilot Activity

Driver Event	Co-Pilot Activity				
	Monitoring	Assisting			
		Co-Pilot Input	Alerting Driver	Restoring	Emergency
driver is **not** in drowsy/distracted phase	✔	✖	✖	✖	✖
driver is in drowsy/distracted phase (sending alert signal)	✔	✔	✔	✖	✖
driver is in drowsy/distracted phase and **not** responding	✔	✔	✔	✖	✔
driver is in drowsy/distracted phase and regain awareness	✔	✖	✖	✔	✖

As summary, Co-Pilot activity regarding the driver event is shown in Table 2.1. Monitoring is becoming a non-stop activity for Co-Pilot and sub function in assisting is depending to driver event phase.

Furthermore, the driving automation level in Fig. 1.2 is being compared with the sequence diagram of Fig. 2.9 and 2.10. The similar processes will have the same label letter, and it is shown in Fig. 2.16. Label A is the transition from “Driver Only” to “Highly Automated”, and the sequence message when driver is distracted or drowsy. Next, label B is the transition from “Highly Automated” to “Minimum Risk State”. The latter state is the condition where Co-Pilot is judging the driver respond and if the situation becomes worse, the driver is not responding to any alert signal, this state will operate an emergency stop function as a final solution for the critical condition. Finally, label C is the transition from “Minimum Risk State” to “Driver Only”. If driver responds to any alert signal and Co-Pilot considers that driver to be fit for driving, the automation level is transformed to its first operation level. Co-Pilot will change its activity to monitoring only.

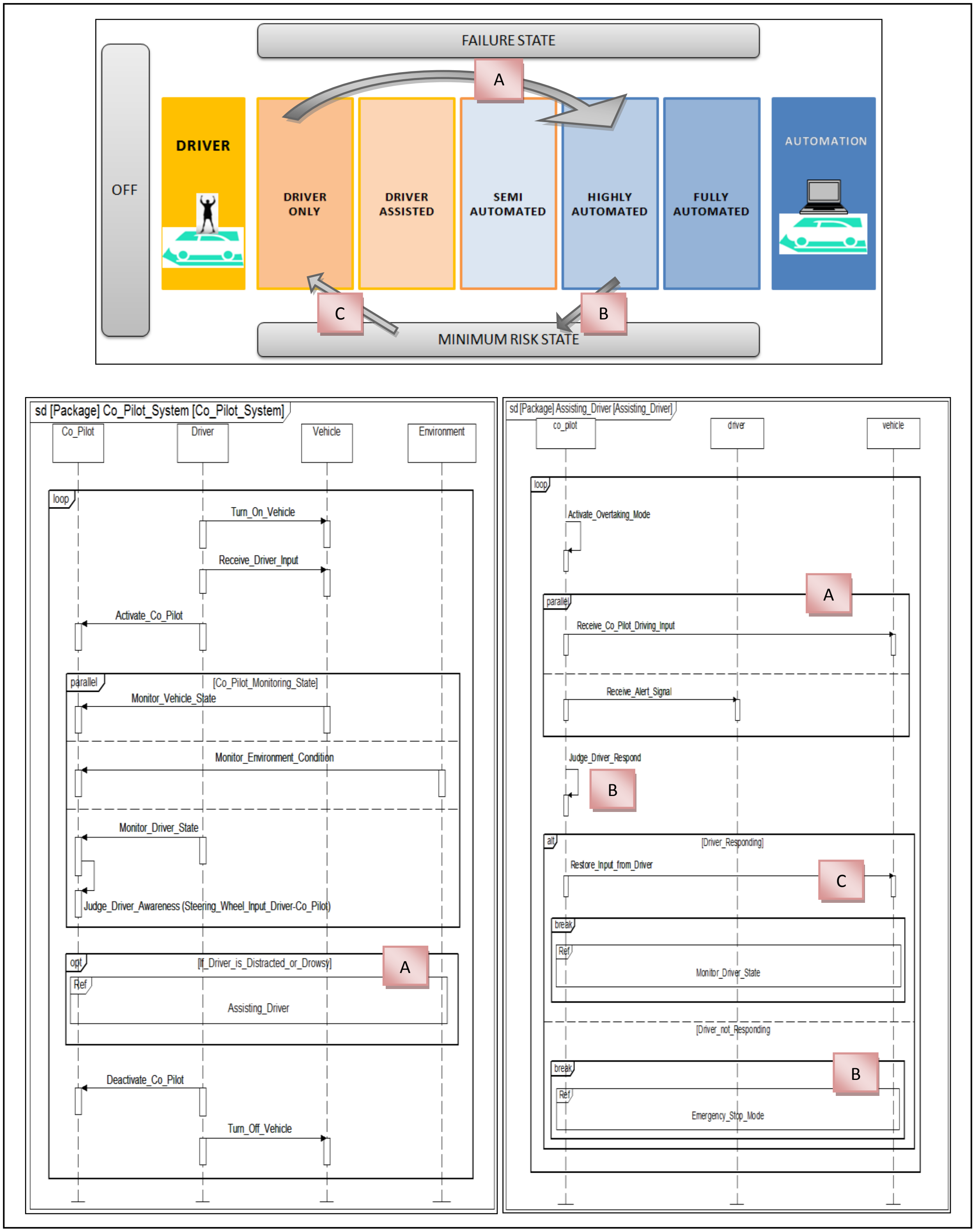


Fig. 2.16 Relation of Highly Automated with MBSE for Co-Pilot Design

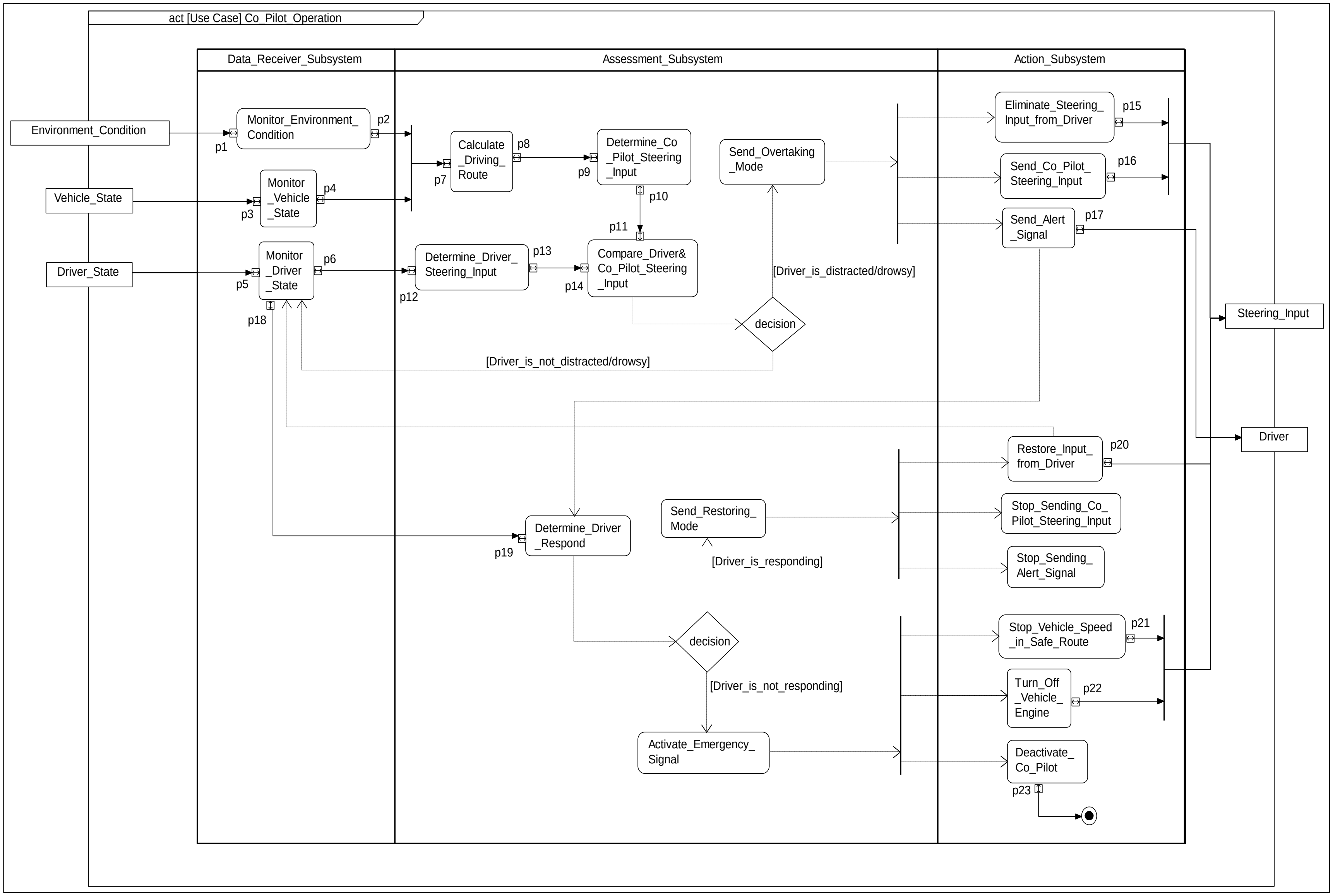


Fig. 2.17 Activity Diagram of Co-Pilot

Fig. 2.17 is mentioning about an Activity Diagram of Co-Pilot's operation. Data Receiver subsystem is monitoring the VDE, and the object flow will goes in to Assessment subsystem. In principle, the assessment process is to judge driver awareness function. The judging function consists of calculating driving route, determining Co-Pilot steering input, determining driver steering input and comparing driver and Co-Pilot steering input. To judge the driver awareness is considered as a vital parameter in the simulation. Next, after comparing driver and Co-Pilot steering input, Assessment subsystem has to make a decision. There are two results of decision. In the first result, the Assessment subsystem considers Driver is in distracted or drowsy situation. This danger situation will force Action subsystem to run overtaking process using a switching mechanism. After the Assessment subsystem sends the overtaking mode, the control flow will makes Action subsystem to run actions for eliminating steering input from driver, sending Co-Pilot steering input, and sending alert signal. However, in the second result, the Assessment subsystem considers the driver is in normal situation. This normal condition makes the activity flow to goes back to beginning process, as monitoring the driver state. The amount of time for begin the overtaking process is considered as a critical parameter in the simulation. During sending the alert signal, the Assessment subsystem will determine driver response using the information flow coming from monitoring the driver state. There are two outcomes for deciding the driver respond. The first outcome is that the Assessment subsystem considers Driver gives respond toward the alert signal. The Action subsystem will conduct actions for restoring input from driver, stopping to send Co-Pilot steering input and alert signal. In the second outcome, the Assessment subsystem considers Driver gives no respond at all toward the alert signal. Therefore, the Action subsystem will run emergency action that consists of stopping the vehicle speed in the safe route, turning off the vehicle engine and deactivating the Co-Pilot system.

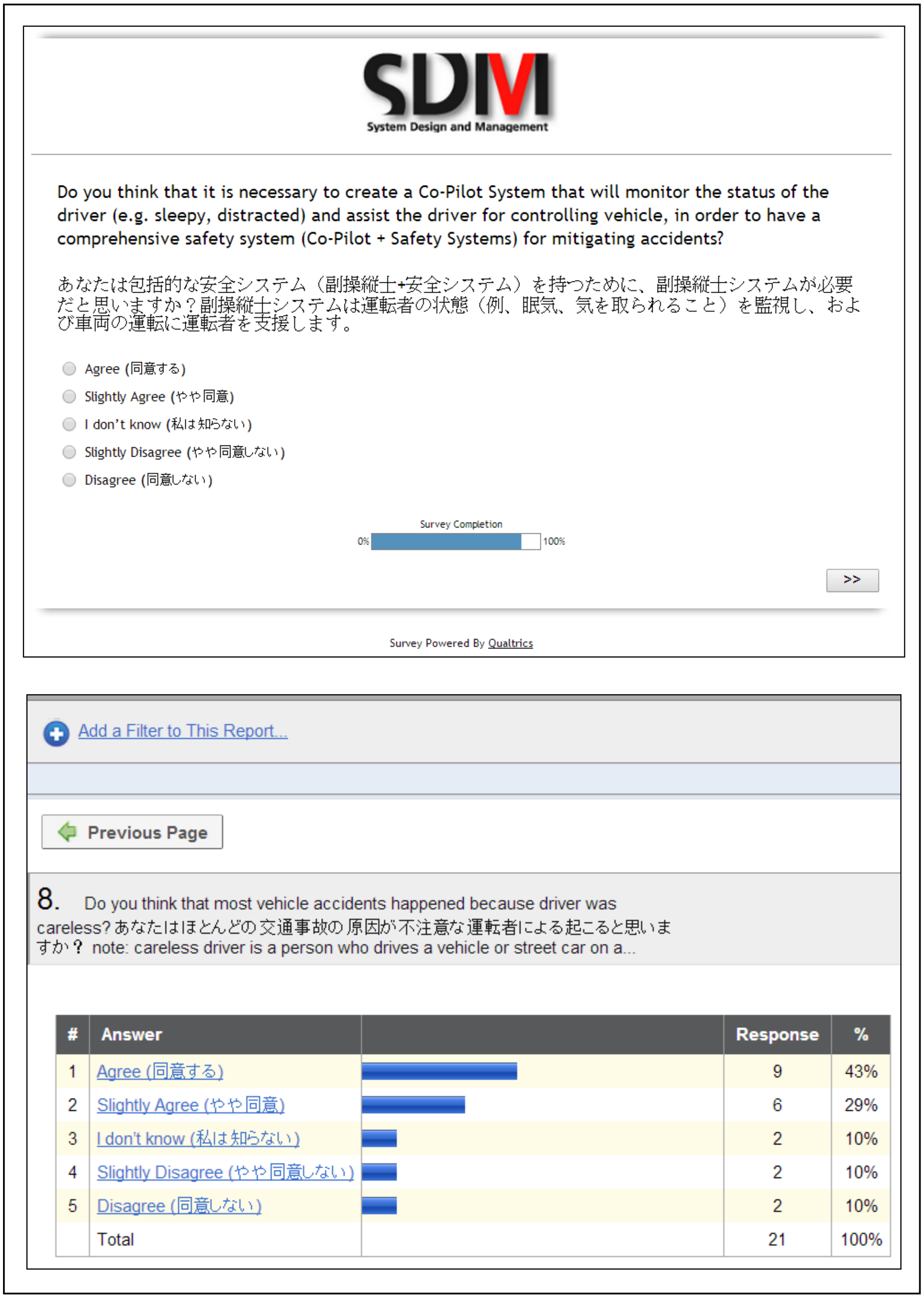
2.3 Validation of Co-Pilot Design using Questionnaire

In this research, questionnaire is used for a method of validation. There are 18 questions in total, and in form of bilingual language, English and Japanese. In this questionnaire, 7 questions are about participant background, 3 questions are about participant opinion for vehicle accident, 4 questions are about participant opinion for driver reliability, and 4 questions about participant opinion for vehicle safety system. The detail of the questionnaire is in the Appendix.

As a result of the questionnaire, numbers of participant are 21 people. For participant background, based on the sex, 18 respondents (86%) are male, and based on respondent age, 18 respondents (86%) are in range 21-40 year old and 2 respondents (10%) are in range 41-60 year old. Next, based on respondent origin, the outcomes are 16 respondents (76%) are from Asia, 3 respondents (14%) are from Europe, 1 respondent each are from America and Africa. Based on respondent work type, the results are 1 respondent is from Government Employee, 2 respondents are from Automotive Industry Company, 13 respondents (62%) are student, and 5 respondents (24%) are from other category.

Furthermore, 17 respondents (81%) can drive a car or motor cycle and 17 respondents (81%) poses a driving license. Based on number of accident, 7 respondents (33%) stated never had any accident and 10 respondents (48%) experienced for 1-3 times. Not all student who participate in this questionnaire are from SDM student, at least 2 people are from other university.

Based on accident opinion, over 70% respondent select agree and slightly agree for question that asked accident happen because of careless driver, and based on vehicle safety system, almost 70% respondent agree to consider building a Co-Pilot System inside vehicle that already equipped with a Safety System (ABS or VSC).



SDM
System Design and Management

Do you think that it is necessary to create a Co-Pilot System that will monitor the status of the driver (e.g. sleepy, distracted) and assist the driver for controlling vehicle, in order to have a comprehensive safety system (Co-Pilot + Safety Systems) for mitigating accidents?

あなたは包括的な安全システム（副操縦士+安全システム）を持つために、副操縦士システムが必要だと思いますか？副操縦士システムは運転者の状態（例、眠気、気を取られること）を監視し、および車両の運転に運転者を支援します。

- Agree (同意する)
- Slightly Agree (やや同意)
- I don't know (私は知らない)
- Slightly Disagree (やや同意しない)
- Disagree (同意しない)

Survey Completion

0% 100%

>>

Survey Powered By Qualtrics

Add a Filter to This Report...

Previous Page

8. Do you think that most vehicle accidents happened because driver was careless? あなたはほとんどの交通事故の原因が不注意な運転者による起こると思いますか？ note: careless driver is a person who drives a vehicle or street car on a...

#	Answer		Response	%
1	Agree (同意する)		9	43%
2	Slightly Agree (やや同意)		6	29%
3	I don't know (私は知らない)		2	10%
4	Slightly Disagree (やや同意しない)		2	10%
5	Disagree (同意しない)		2	10%
	Total		21	100%

Fig. 2.18 Print Screen of a Question (source: sdmkeio.co1.qualtrics.com)

3. CO-PILOT IN SIMULATION

3.1 Driver in Dymola Application

Dymola application provides driver model in its simulation library. The driver model that has similar function as human driver is found in closed-loop driver model which consists of three sub process model. The first sub-model is Perception, which gather information such as road ahead and dashboard information. The second sub-model is Planner which producing a path for vehicle to go to. Last sub-model is Tracker that creates a steering wheel input for vehicle.

In this research, driver is depicted as a person who has problem during driving. This problem may in the form of losing awareness or attention. The common examples that causing this problem are drowsy, reading some documented material and talking on the phone. In addition, based on one of the SAE's research paper [**7**], drowsy is happen because driver is exhausted and the worn-out experience changes the sensing level of the driver. Drowsy driver is assumed as a driver who has slow reaction and has a difficulty to stay in correct lane. Moreover, Harald Freij in his paper [**8**], tries to model an unaware driver in to two outcomes. First, if the driver's eye seeing other area rather than to forward road, driver's command will not continuously exist. This is mean, that driver input is depicted as intermittent input. Second, there is an offset angle that added in to steering wheel angle by driver in that situation. These two outcomes are considered as the representation of distracted driver.

Therefore, a gain block and a delay block are useful for creating an offset value and a slow respond. These blocks are placed intentionally inside the closed-loop driver model specifically in the tracker sub-model. With a gain block, steering wheel is becoming adjustable into a certain offset value, and with a delay block, the driver reaction is easy to be change in order to copy an image of driver's late respond.

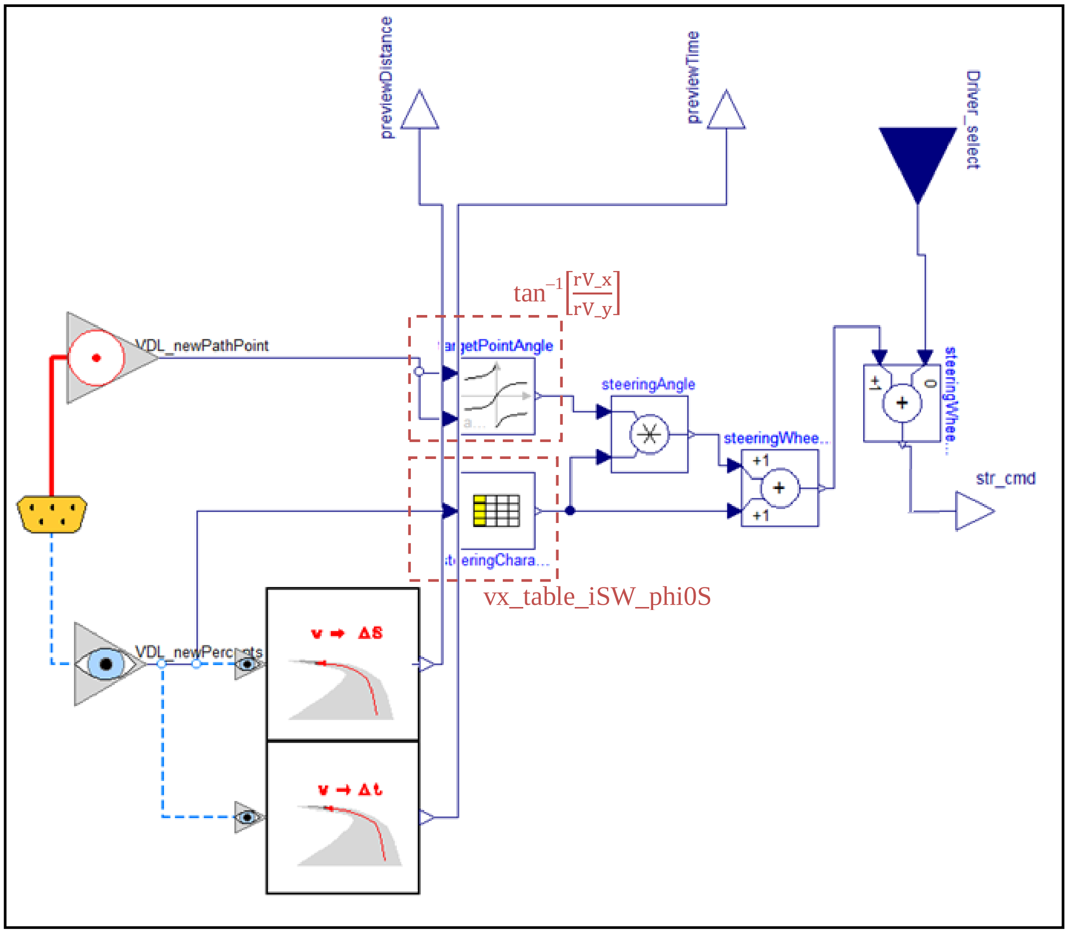


Fig. 3.1 Tracker Block in Dymola

Adding the information, a tracker sub-model is useful to calculate the value of steering angle command (str_cmd), as seen in Fig. 3.1. Based on the reference [**9**], the equation for steering angle command is:

$$str\_cmd = \tan^{-1}\left[\frac{rV\_x}{rV\_y}\right]*vx\_table\_iSW\_phi0SW + vx\_table\_iSW\_phi0SW \qquad \text{(eq. 1)}$$

where:

rV_x : longitudinal distance along path between target point and current vehicle position

rV_y : lateral distance along path between target point and current vehicle position

vx_table_iSW_phi0SW : steering characteristic

3.2 Defining Co-Pilot in Dymola Application

Benchmark problem model from JSAE & SICE is provided with vehicle, driver, and vehicle stability control blocks. In this model, environment is in the form of gravity, road surface, and wind source. Next, for simulating the desire design concept as explained in chap. 2, a Co-Pilot block has to be built in this model. Fig. 3.2 is showing the existence of Co-Pilot in benchmark model.

However, there are several adjustment have to be made for this simulation. Due to complexity of the model and its sub model, the Co-Pilot block seems only connects with the driver block and not the vehicle. This is happen because the output from tracker is being used as the same source for driver and steering wheel input. Also, in driver's side, a gain and a delay blocks are placed for making driver in drowsy or distracted situation.

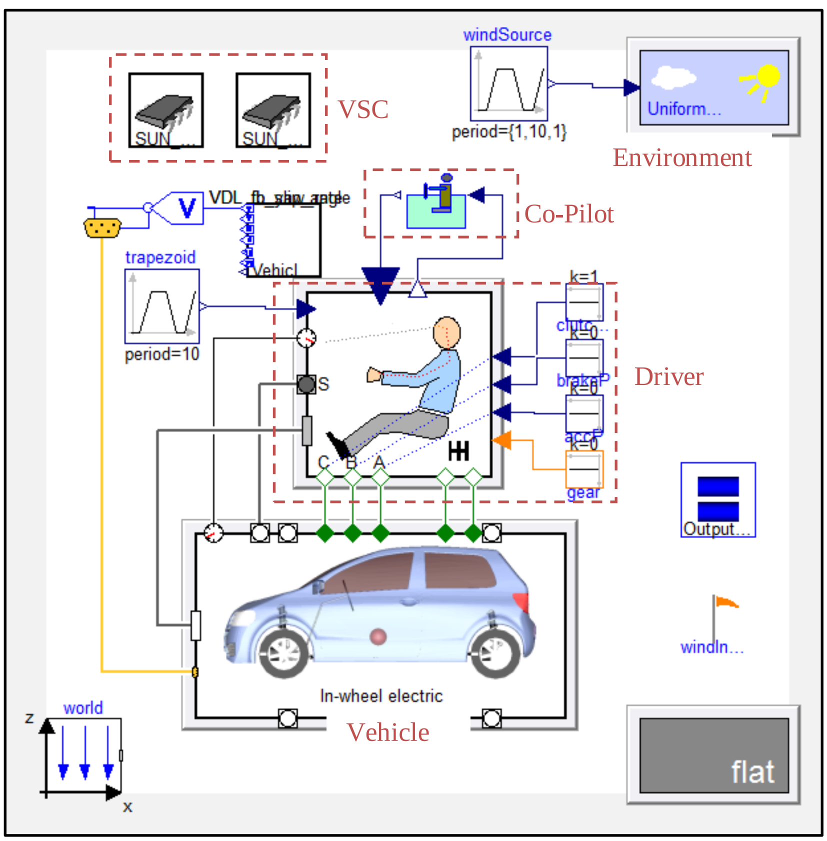


Fig. 3.2 VDE Model with Co-Pilot in Dymola

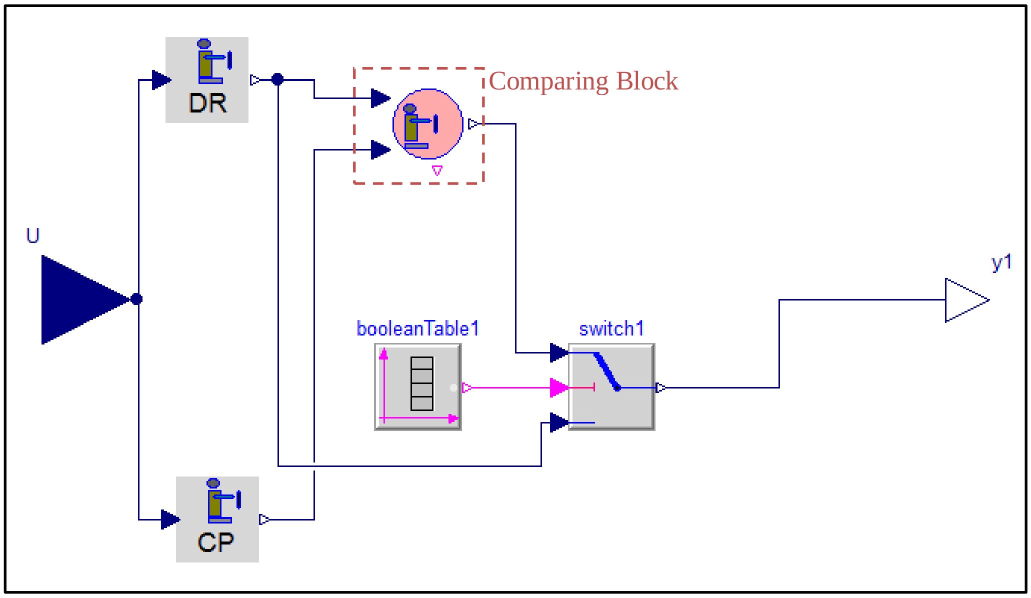


Fig. 3.3 Co-Pilot in Dymola

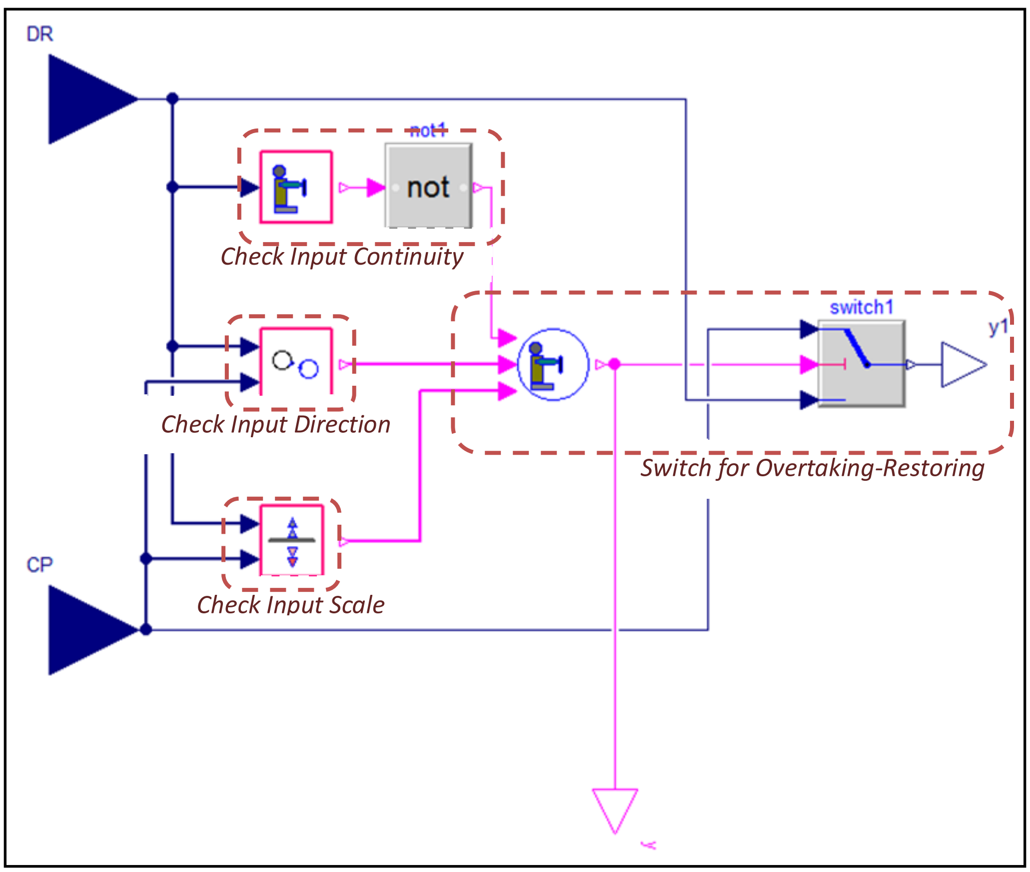


Fig. 3.4 Comparing Block in Dymola

Fig 3.4 is mentioning about model in Dymola for comparing driver input against the Co-Pilot calculation, in order to define driver state, the state which decomposed in to distracted/drowsy (Driver is not OK) and good awareness (Driver is OK). In this model, "DR" represented the steering wheel input comes from driver and "CP" depicted steering wheel input calculation comes from Co-Pilot. There are three processes for checking driver state. First is check input continuity. If no input comes from driver [IF DR = 0], it means driver state is not OK. Next is check input direction. If driver input has a value but has different direction compare to Co-Pilot calculation [ELSE IF DR $\neq$ 0 AND CP*DR $\leq$ 0], the conclusion of driver state is not OK. Last is check input scale. If driver input has a value and in same direction but different number compare to Co-Pilot calculation [ELSE IF DR $\neq$ 0 AND CP*DR > 0 AND |CP|-|DR| $\neq$ 0], the status of driver state is not OK.

After comparing process, if the result is stating that Driver is not OK, switch will automatically goes to Overtaking. It means the source of steering wheel input will change from driver to Co-Pilot calculation. However in the process, if the comparing result is mentioning that driver is OK, switch will goes Restoring, in this situation, the source of steering wheel input will come from driver.

In addition, from Makoto Itoh et al jounal [**10**], they made an operation rule for crash evasion procedure. The rule is based on time-to-collision (TTC) and driver's command. The procedure is dividing TTC into two zones. The first zone is analyzing the existence of driver's steering command and vehicle optimal route. The second zone is taking control of steering command in order to have full stops before the obstacle, regardless the existence of driver's command. In principle, the procedure of dividing zones for avoiding danger considered to be useful by this research.

3.3 Dymola Simulation Result

In benchmark problem, there are sets of situation which available for simulation. This paper is using the situation where Micro EV-IWM equipped with VSC and experienced a side wind. The time of simulation is 10 second, and the side wind starts from 3 until 6 second. Vehicle speed is around 60 km per hour and side wind speed is in 20 m/s.

Moreover, there are several conditions that have to be defined before making an illustration of distracted or drowsy driver. The conditions to describe distracted or drowsy driver is in the form that driver is the person who have a delay, or an offset, or without steering input. Next, the simulation result of distracted or drowsy driver is going to be compared with the simulation result where driver has no problem.

In the result graph as seen from Fig. 3.6 until 3.9, "Driver" is for driver who behaves abnormal, and "Co-Pilot" is the Co-Pilot's calculation. "Driver ok" is for the result where driver behave normal and "Co-Pilot involve" is for the result when driver is in improper behavior and after a certain of time, Co-Pilot will takes over the steering wheel input.

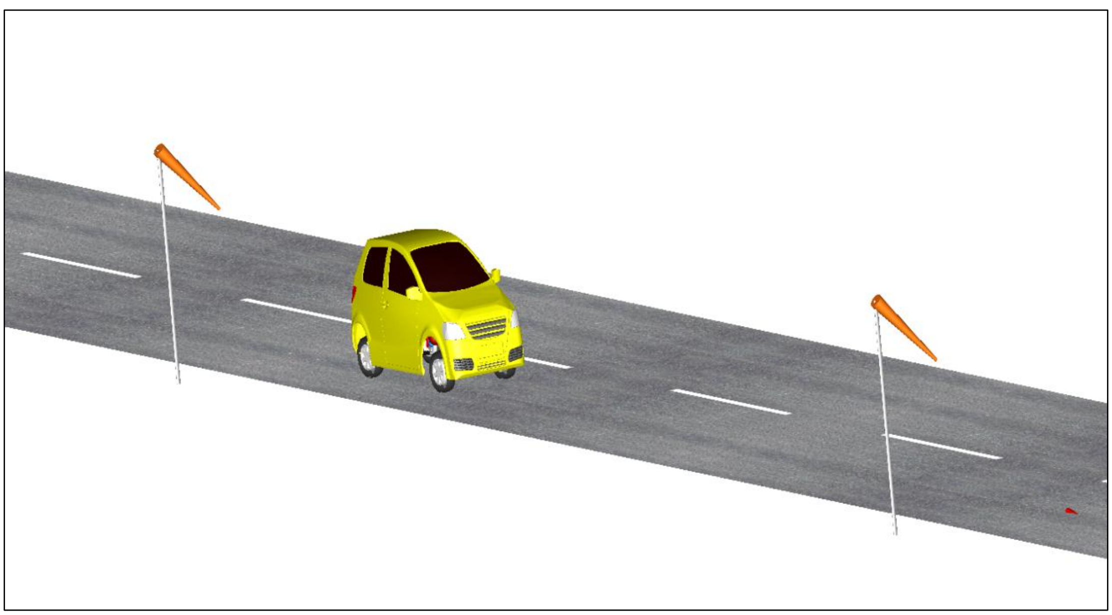


Fig. 3.5 Print Screen of Dymola Simulation

3.3.1 Driver without Steering Input

In this condition, no steering input comes from driver and from 4 second, Co-Pilot start to take over for sending steering input into vehicle.

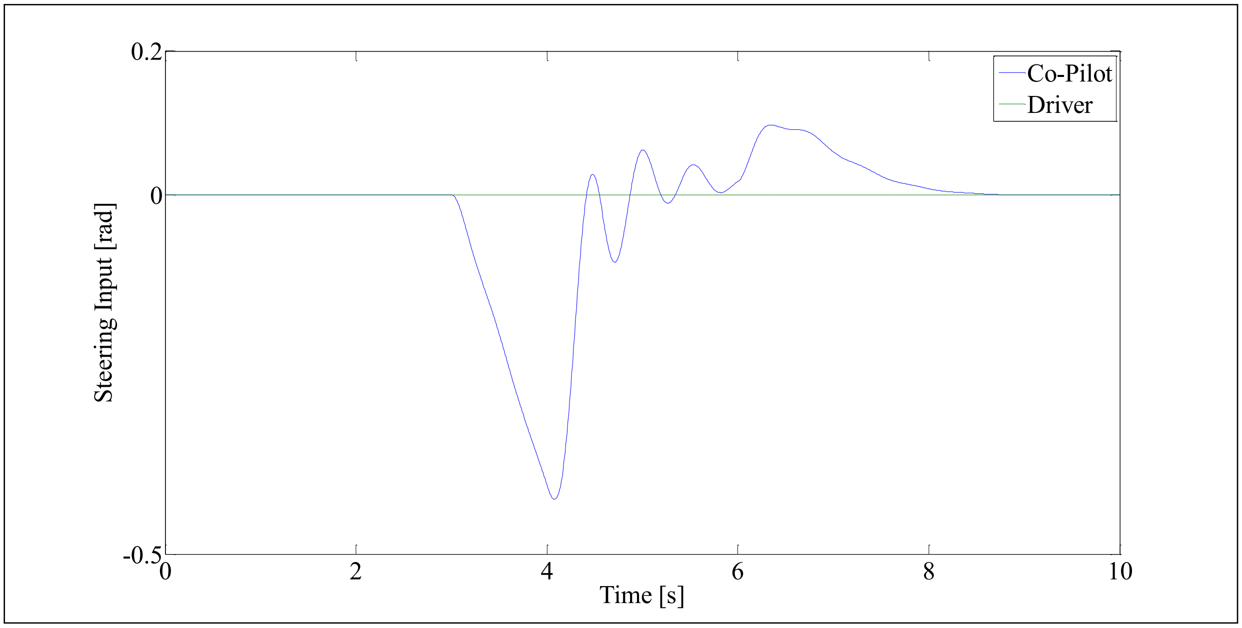


Fig. 3.6.a Comparison between Driver and Co-Pilot Steering Input

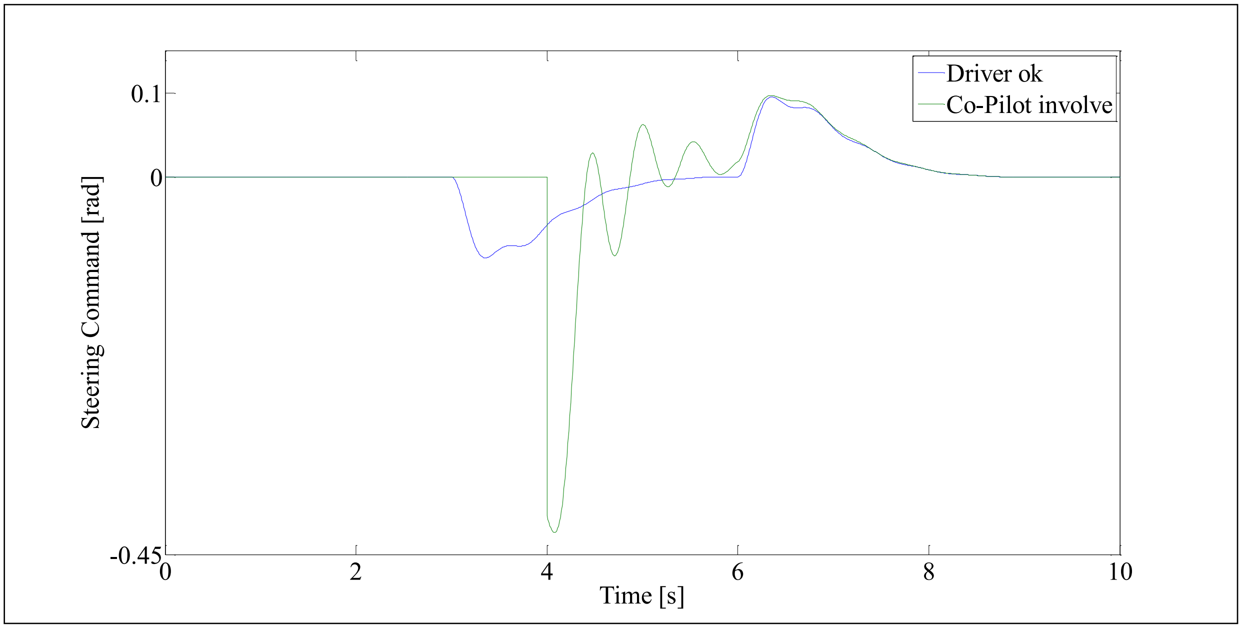


Fig. 3.6.b Steering Command Result

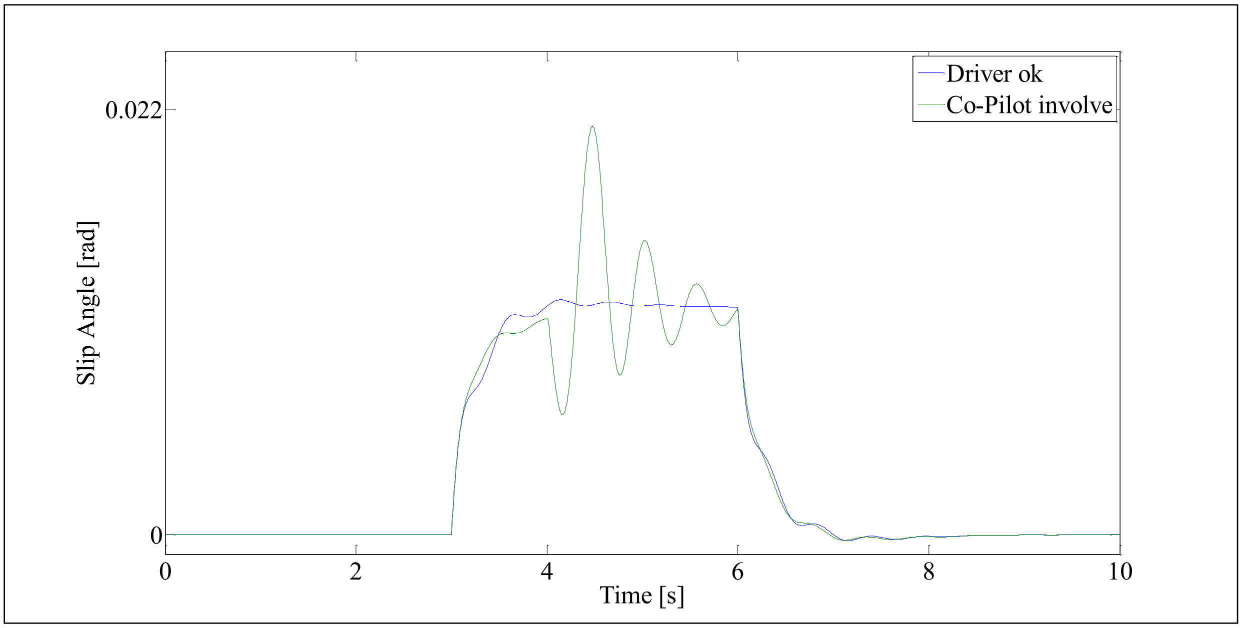


Fig. 3.6.c Slip Angle Result

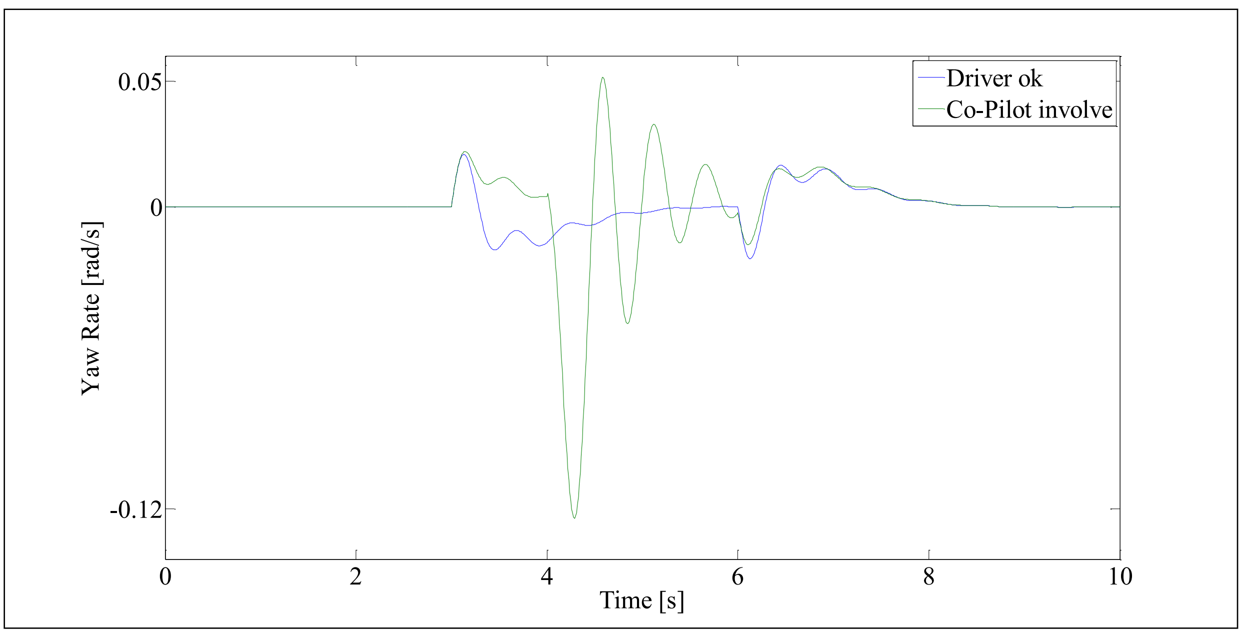


Fig. 3.6.d Yaw Rate Result

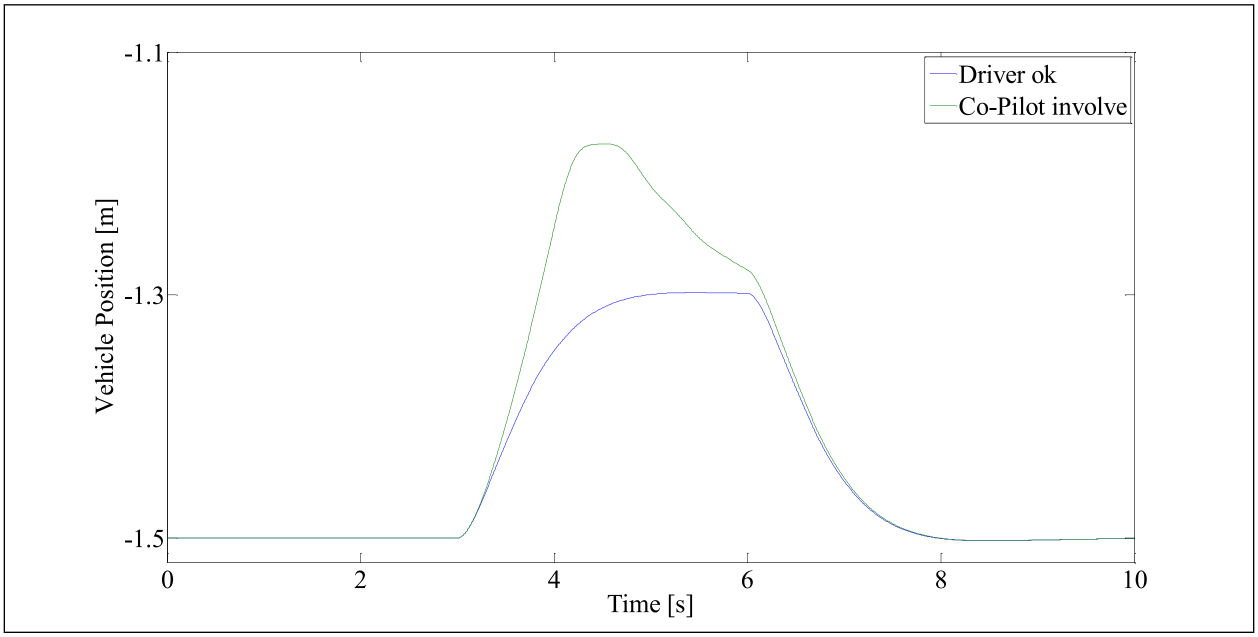


Fig. 3.6.e Vehicle Position Result

3.3.2 Driver with a Delayed Steering Input

In this condition, there is a 1 second delay for driver steering input and from 4 second, Co-Pilot start to take over for sending steering input into vehicle.

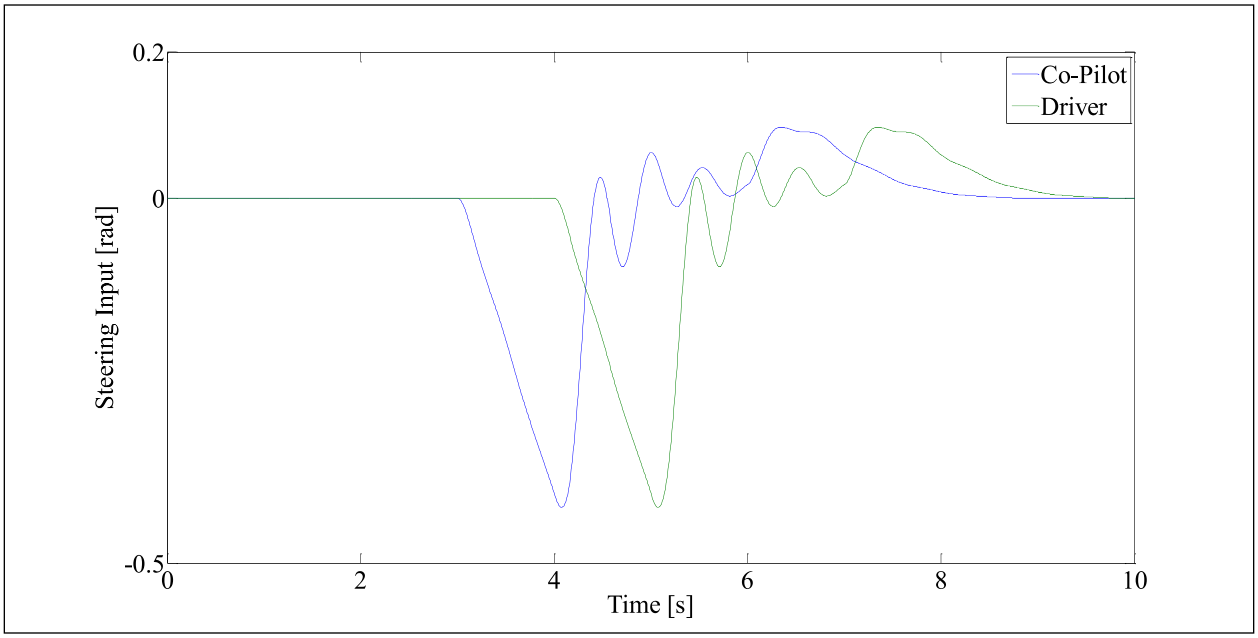


Fig. 3.7.a Comparison between Driver and Co-Pilot Steering Input

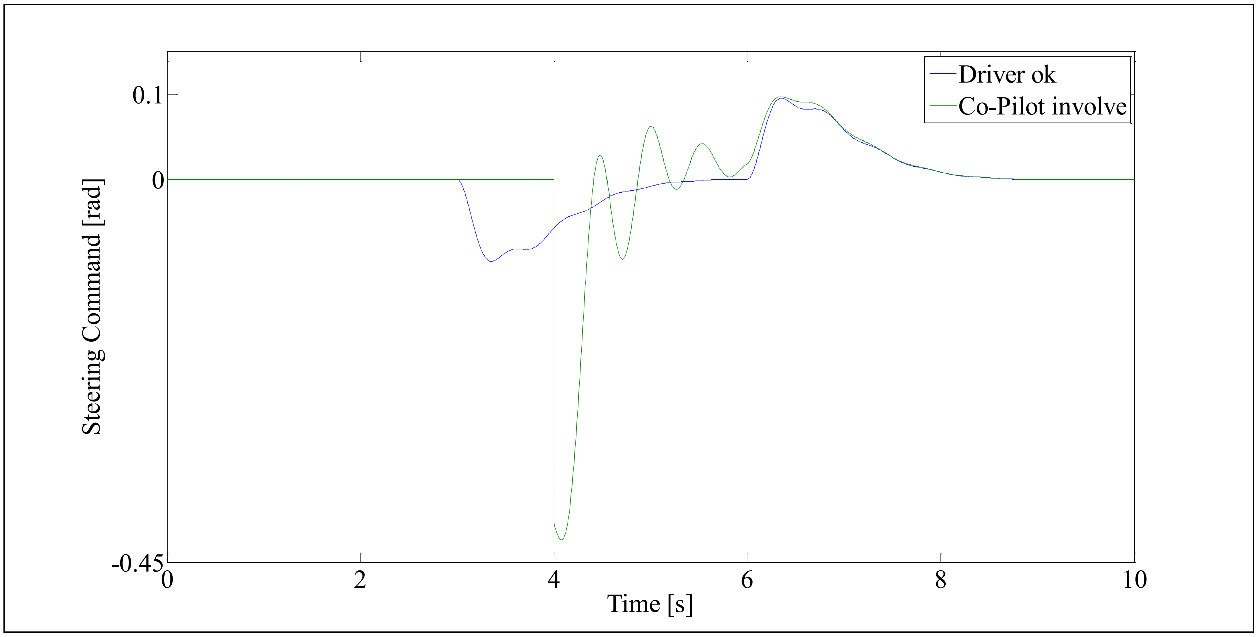


Fig. 3.7.b Steering Command Result

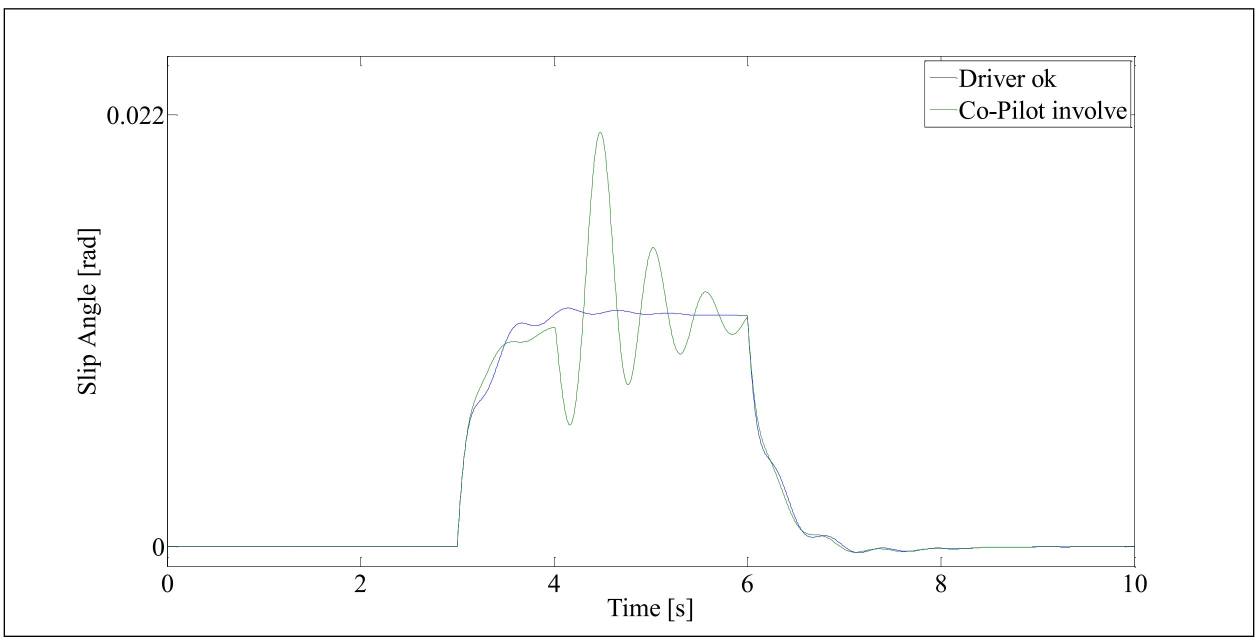


Fig. 3.7.c Slip Angle Result

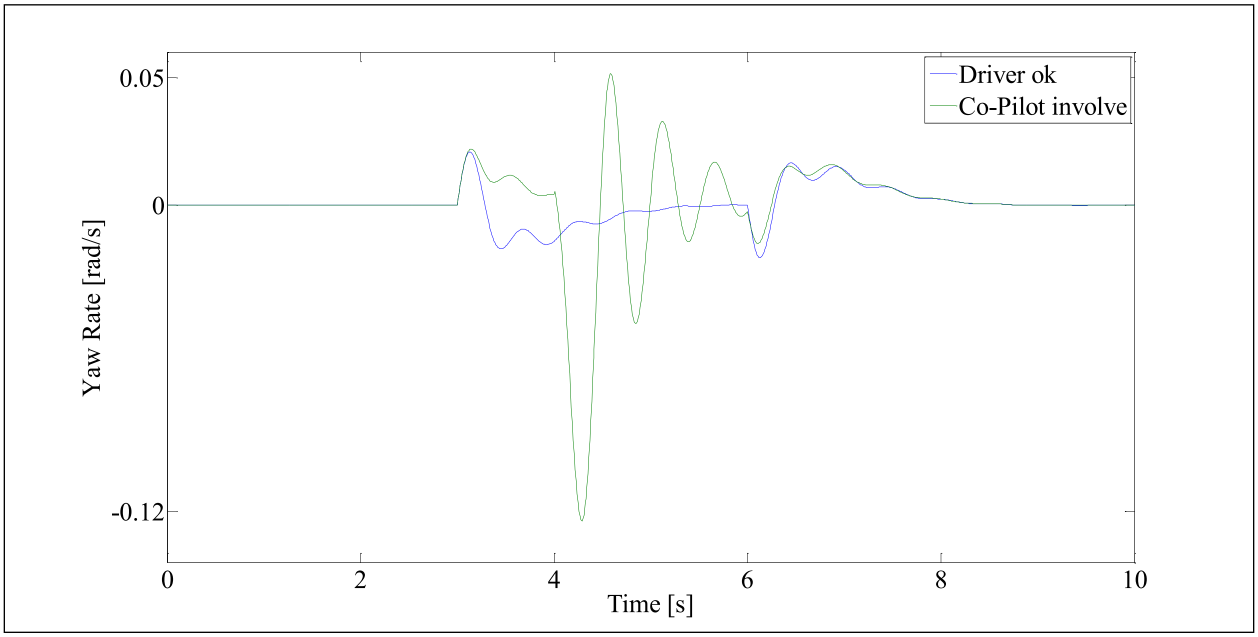


Fig. 3.7.d Yaw Rate Result

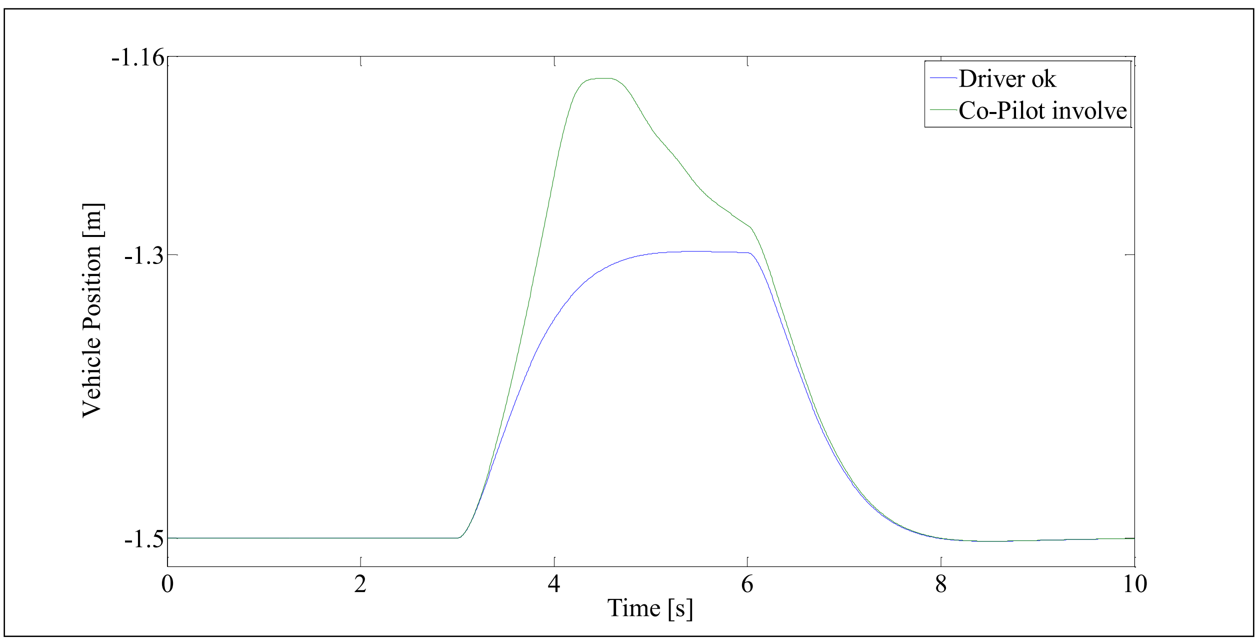


Fig. 3.7.e Vehicle Position Result

3.3.3 Driver with an Offset Steering Input

In this condition, there is a 100% offset for driver steering input and from 4 second, Co-Pilot start to take over for sending steering input into vehicle.

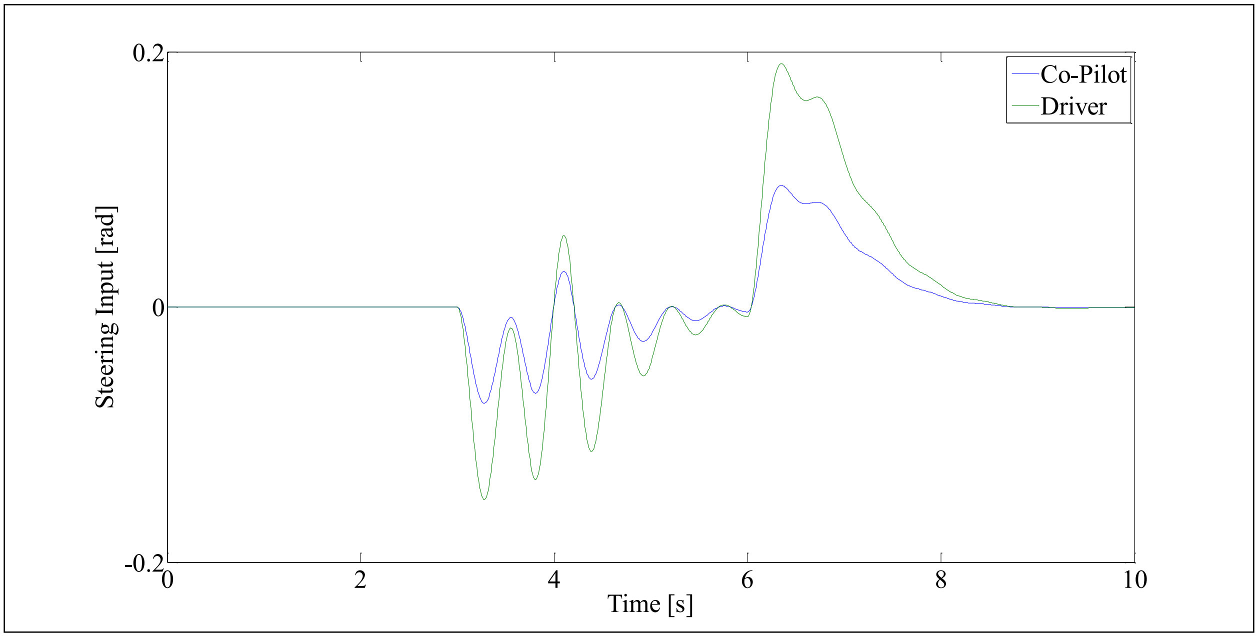


Fig. 3.8.a Comparison between Driver and Co-Pilot Steering Input

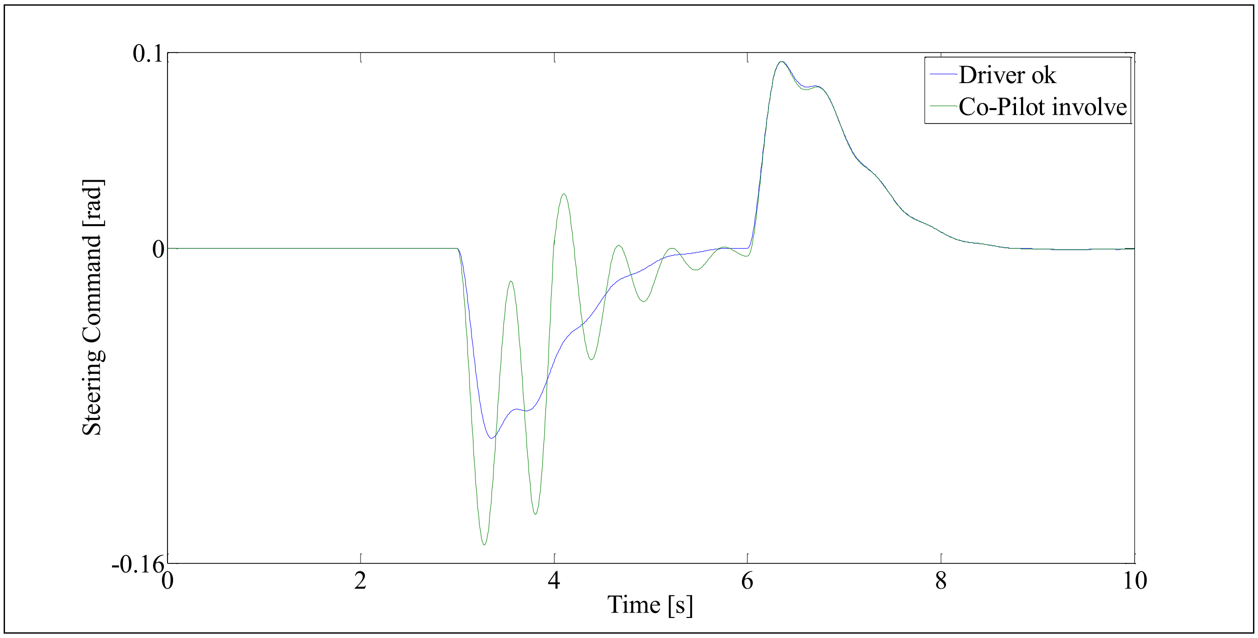


Fig. 3.8.b Steering Command Result

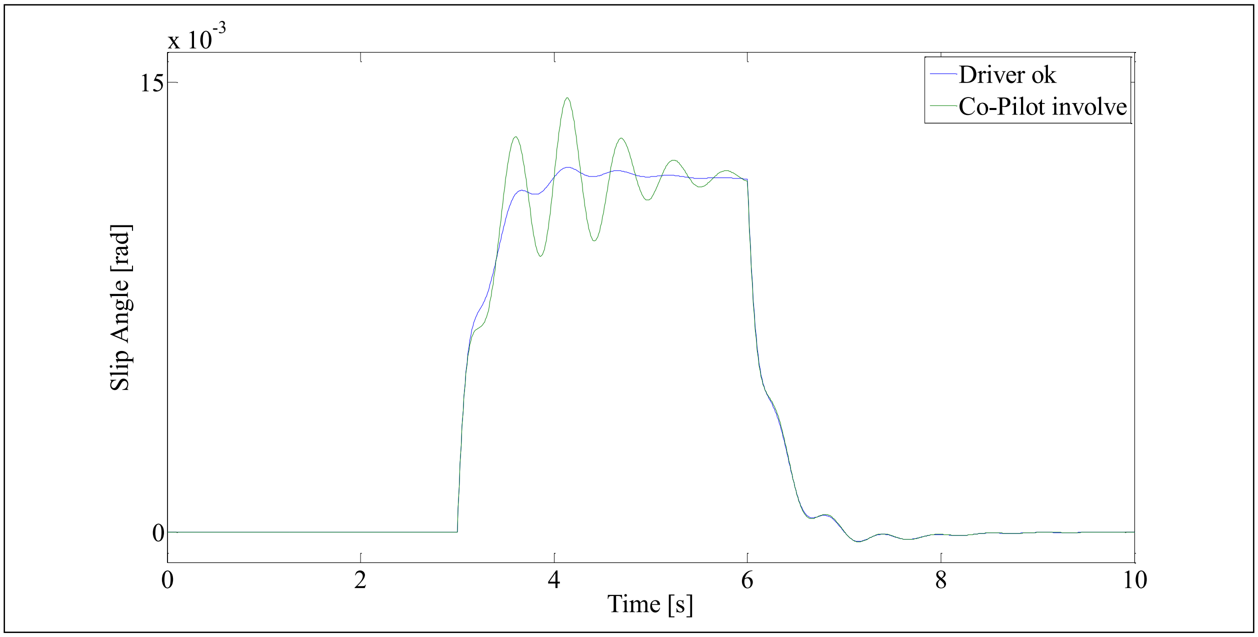


Fig. 3.8.c Slip Angle Result

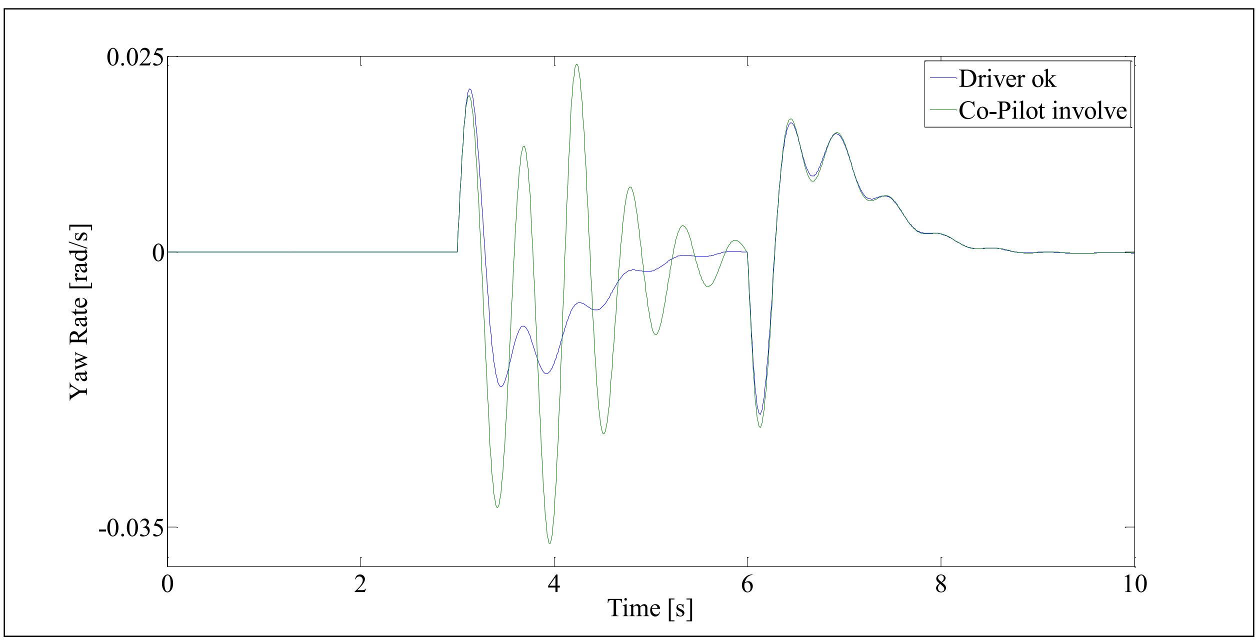


Fig. 3.8.d Yaw Rate Result

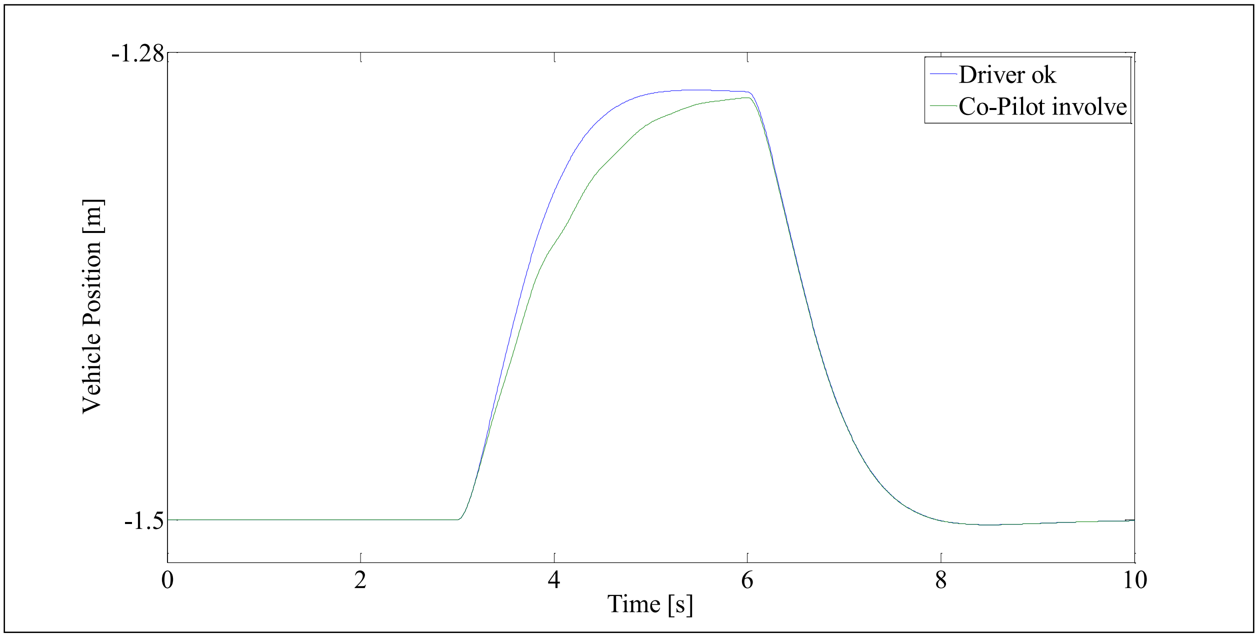


Fig. 3.8.e Vehicle Position Result

3.3.4 Driver with an Offset and a Delayed Steering Input

In this condition, there is a 100% offset and 1 second delay for driver steering input and from 4 second, Co-Pilot start to take over for sending steering input into vehicle.

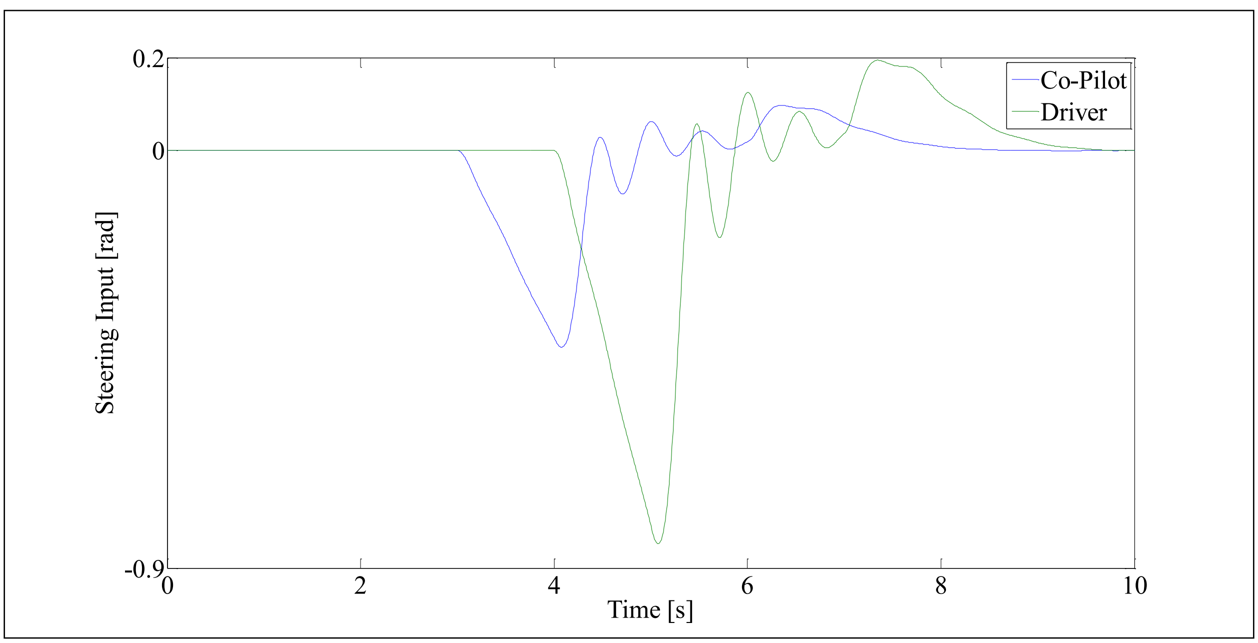


Fig. 3.9.a Comparison between Driver and Co-Pilot Steering Input

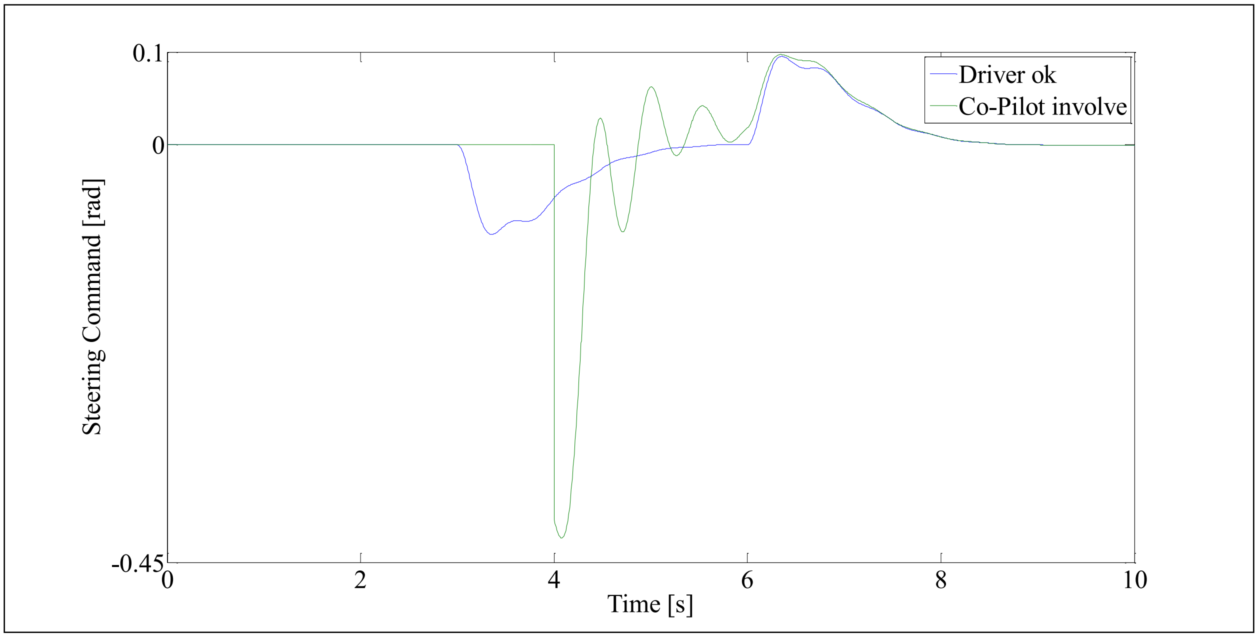


Fig. 3.9.b Steering Command Result

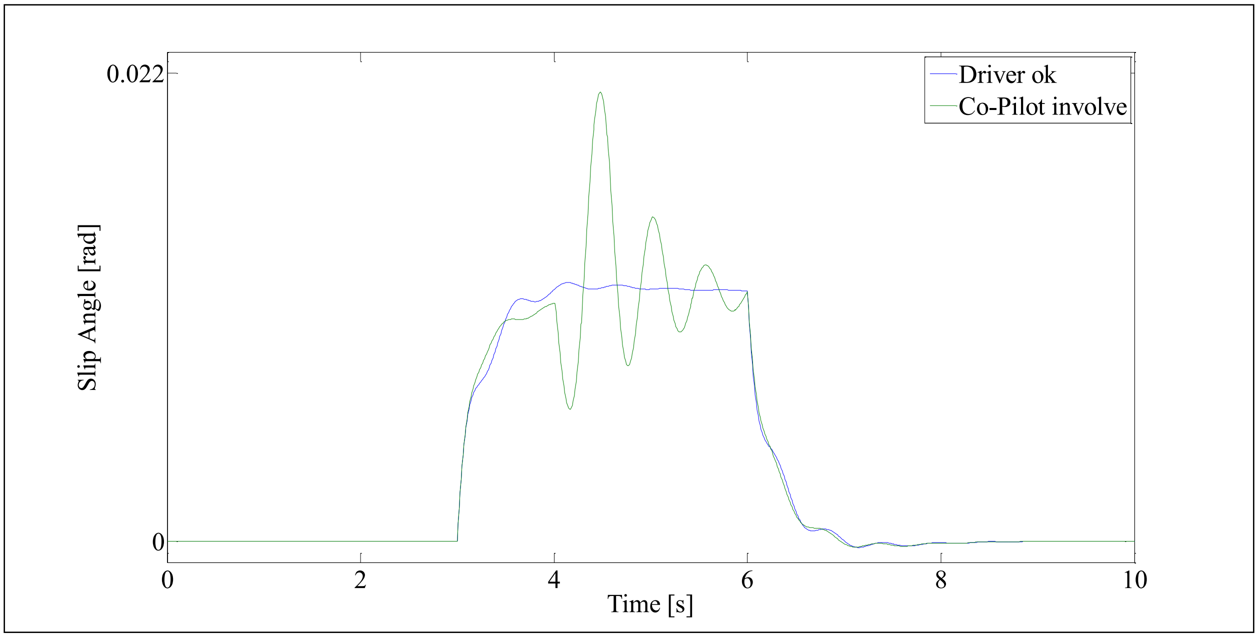


Fig. 3.9.c Slip Angle Result

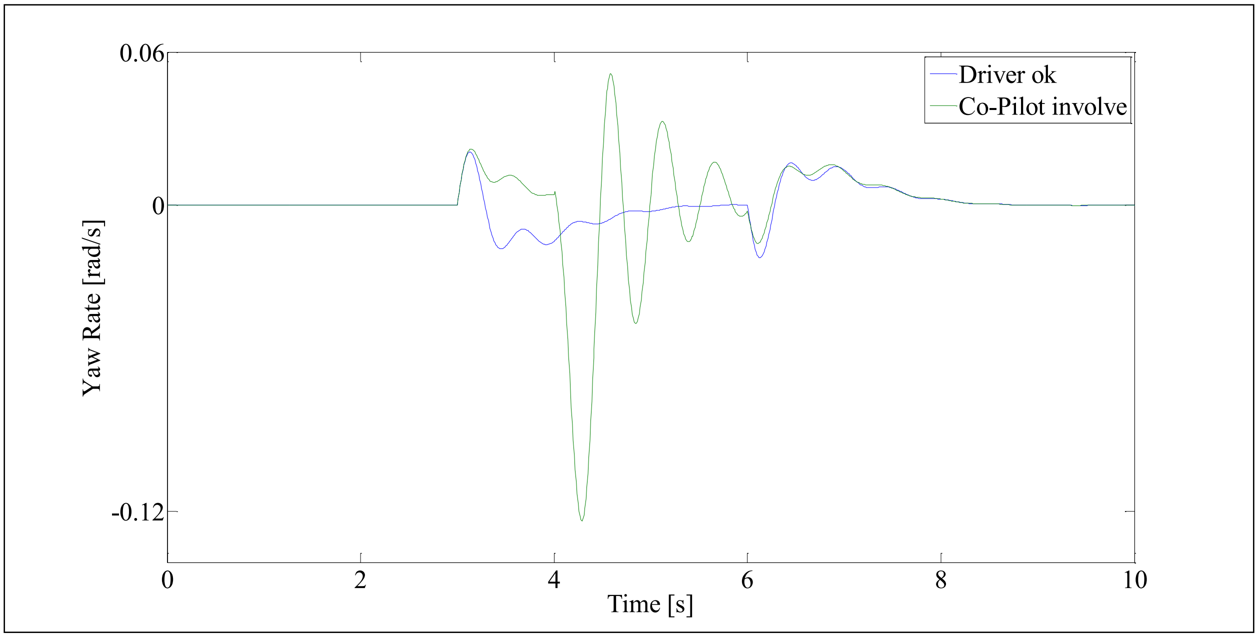


Fig. 3.9.d Yaw Rate Result

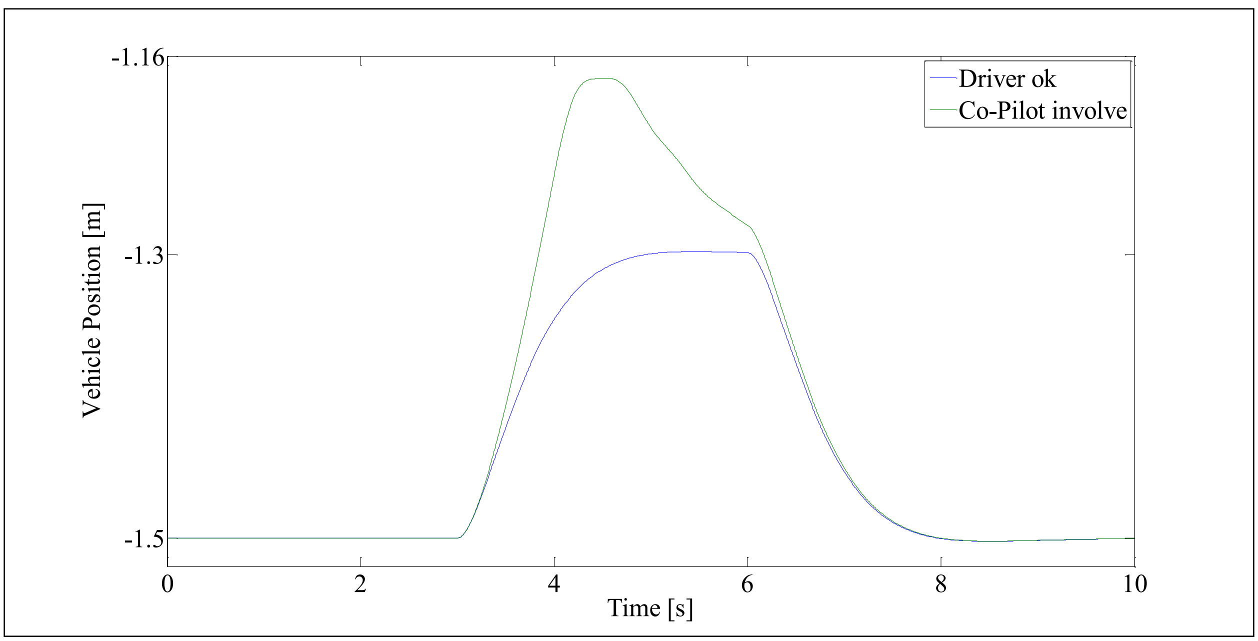


Fig. 3.9.e Vehicle Position Result

4. DISCUSSION

In building Co-Pilot system using several methods, from MBSE to Dymola simulation, there are a lot of procedure and consideration that taken in to account. The process to judge the driver's state is the one that also needs further explanation. In Table 4.1, if driver is distracted or drowsy, it is believe that there is a certain pattern showing this behavior in indicators, and electronic device can read this pattern too. Due to model complexity, only steering wheel input is selected to be useful for depicting this driver's behavior in Dymola simulation. However, there is a question regarding this selection: does this one parameter is sufficient to model the distracted or drowsy driver, or should add other parameters.

Table 4.1 Relationship between Driver State Indicator and Simulation Parameter

Driver State Indicator	Device	Simulation Parameter
- Diver's eyes movement - Driver's head rotation - Steering Wheel Input Activity - Acceleration-Brake Pedal Activity	- Camera - Infra red sensor - Accelerometer - Angle sensor	Steering Wheel Input has: - No Input - Delay Input - Offset Input - Combination above

Also, there is another consideration that requires explanation. This consideration is in the process of eliminating and restoring steering input from driver, what is the real device for this switching action. Based on the reference [**1**], there is a device named as "drive by wire" system that writer believe can manage to perform the switching action. All driver input is transformed through electric current by drive by wire system, and this current latter on, controls the actuator device. If engineer can redesign and reshape the drive by wire system and can add Co-Pilot into the system, the switch function will become available for real uses in the future.

Moreover, the consideration for sending alert signal and judging driver respond need to be explained. Table 4.2 is explaining the possible way for driver to respond. In this situation, Co-Pilot is controlling the steering wheel. Therefore, the driver, as the person that Co-Pilot's concerning about, has to deliver proper respond for taking back the steering control. In writer perspective, the effective way for driver to retake the steering wheel control is by following all Co-Pilot's instruction and this instruction is including which button to push or screen to touch.

Table 4.2 Relationship between Alert Signal and Expected Respond

Alert Signal	**Device**	**Expected Respond**
- Sound - Human Voice - Steering and Chair Vibration - Instruction Display	- Speaker - Vibration motor - Touch Screen - Button panel	Driver is regain awareness: - follow the instruction - push the correct button - touch the correct display

In the simulation result as mention in chap. 3.3, the time for Co-Pilot to takes over the steering control is already set in 4 second. It means that the Co-Pilot is active in 1 second after vehicle experienced the side wind. In other words, Co-Pilot is set active 1 second after critical situation. There is a question regarding what will happen if the time for Co-Pilot to active changes from 1 second or more.

Therefore, writer is conducting further simulation processes that the changing time for Co-Pilot to active. In the result, after changing the time and running more simulation in the side wind situation, there are situation where the result are failed. This failed result is happen because the vehicle is driven away from the road, or vehicle is crashed out due to high yaw rate. Table 4.3 is showing the possible time for Co-Pilot to take over the steering wheel with no failed result and it is also regards to with the same description of driver condition as mention in chap. 3.3.

Table 4.3 Possible Time for Co-Pilot's taking over During Simulation

Driver Condition	**Co-Pilot's Taking Over Time**
Driver without Steering Input	at 4.5 second
Driver with a Delayed Steering Input	at 5 second
Driver with an Offset Steering Input	at 6 second
Driver with an Offset and a Delayed Steering Input	at 4.75 second

5. CONCLUSION

In this study, Co-Pilot is defined as an artificial system that consists of Data Receiver, Assessment, and Action subsystems. Co-Pilot has functions to detect driver state, vehicle state, and environment condition. It also has functions to compare driver input with Co-Pilot calculation, take over the steering input when driver is not suitable for driving, send alert signal to driver, measure driver's respond toward the alert signal, and restore steering input if driver regain self awareness. All of these functions are considered to be sufficient for improving the safety of Micro EV-IWM.

Based on Dymola simulation, distracted/drowsy driver is assumed as a driver who has no steering input, has a delayed steering input, has an offset steering input, or has an offset with a delayed steering input. However, due to the complexity and limitation of Benchmark problem model, some of Co-Pilot functions that consist of sending the alert signal to driver and measuring driver respond toward alert signal, are not showed in this paper.

The phase of deciding parameter for simulation is considered to be important. In this paper simulation process, the parameter consists of the way to judge the driver awareness, the time to begin overtaking process and the switching mechanism for overtaking the steering input. In further simulation process with situation where Micro EV-IWM is facing a side wind, the possible time for Co-Pilot's to takes over steering input are within 4.5 second until 6 second. Based on this time result, the available time for Co-Pilot to take over the steering input during critical condition is really limited.

There are few limitations in this research. First, the driving situation for simulation is only in one situation, Micro-EV facing the side wind. Second, the process to build a Co-Pilot system inside the Benchmark problem model, is not simple due to the complexity of the model, therefore, some adjustments has to be made for running the simulation.

For future work, the numbers of driving situation inside the simulation has should be enlarge in order to cover all driving situation needed. Next, the future process has to build better interfaces between Co-Pilot and Driver, which more comfort, simple and smooth. After that, the future process has to define more parameters such as the appropriate time for taking over the driver's command. Finally, it is suggested if this research is conducted in driving simulator or in the real experiment condition.

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I would also to send my gratitude for my fellow classmates and lab member in Keio SDM, for all their helping hands, ideas, and laughing moments. I also like to thank students and friends who took my questionnaire and delivered useful feedbacks. Personally, I would like to thank Yun-san and Ilham-san, for their help especially during the time when I got stuck using Matlab, Rhapsody and Dymola. Also, I send my gratitude to Kinoshita-san and Mishima-san, for their warm welcome and caring moment. Next, I would also to thank Xiong-Di and Ro-B, for their friendship and caring.

Last but not least, I would like to thank my family in Indonesia, especially my mother, for all their abundant support and prayers to me. Thank you so much.

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A. APPENDIX (QUESTIONNAIRE)

Co-Pilot Questionnaire: 副操縦士　アンケート：

No. 01-07, about participant background

01～07 番号は、参加者のバックグラウンドについて

01. What is your age?　あなたの年齢を教えてください。
    a. under 21 year old　21 歳未満
    b. 21-40 year old　21 から 40 才
    c. 41-60 year old　41 から 60 才
    d. over 60 year old　60 歳以上

02. What is your gender?　あなたの性別を教えてください。
    a. Male　男性
    b. Female　女性

03. Where is your country located?　あなたの国はどこにありますか？
    a. Asia　アジア
    b. Europe　ヨーロッパ
    c. Africa　アフリカ
    d. Australia　オーストラリア
    e. America　アメリカ

04. What is your work?　　あなたの仕事は何ですか？

a. Government Employee　　公務員

b. Automotive Industry Company　　自動車産業会社

c. Student　　学生

d. Others　　その他

05. Can you drive a car or motor cycle?

あなたは車やオートバイを運転することができますか？

a. Yes　はい

b. No　いいえ

06. Do you have any driving licenses?　あなたは、運転免許証を持っていますか？

a. Yes　はい

b. No　いいえ

07. In your life, as a driver, have you ever experienced any accidents?

今まで、あなたは運転者として事故を経験したことがありますか？

a. No　　いいえ

b. More than 3 times　　3 回以上

c. 1-3 times　　1〜3 回

d. I don't drive　　私は車を運転しない

No. 08-10, about participant opinion for vehicle accident

08～10 番号は、車両事故に関する参加者の考えについて

08. Do you think that most vehicle accidents happened because driver was careless?

    あなたはほとんどの交通事故の原因が不注意な運転者による起こると思いますか？

    a. Agree 同意する
    b. Slightly Agree ややや同意
    c. I don’t know 私は知らない
    d. Slightly Disagree やや同意しない
    e. Disagree 同意しない

note:

Careless driver is a person who drives a vehicle or street car on a road without due care and attention or without reasonable consideration for other persons using the road.

注意：

不注意な運転者というのは、他の道路の利用者を注意せずに道路上の車両を運転する人です。

09. Do you think that most vehicle accidents happen because the driver was distracted (e.g. operating cell phone, talking with passenger)?

あなたは、運転者が（例えば、乗客と話すこと、携帯電話を見ること）気を取られたため、ほとんどの車両事故が起こると思いますか？

a. Agree 同意する

b. Slightly Agree やや同意

c. I don’t know 私は知らない

d. Slightly Disagree やや同意しない

e. Disagree 同意しない

10. Do you think that most vehicle accidents happened because the driver was sleepy (drowsy)?

あなたは、運転者が眠かったため、ほとんどの車両事故が起こると思いますか？

a. Agree 同意する

b. Slightly Agree やや同意

c. I don’t know 私は知らない

d. Slightly Disagree やや同意しない

e. Disagree 同意しない

No. 11-14, about participant opinion for driver reliability

11～14番号は、運転者の信頼性に関する参加者の考えについて

11. If you have to drive for several hours, with few or no breaks from driving, do you feel uncomfortable (e.g. muscle pains)?

    あなたは数時間に運転する必要がある場合に運転してから休憩が短期間または全くない時に、不快に感じますか（例えば、筋肉痛）？

    a. Agree 同意する
    b. Slightly Agree ややや同意
    c. I don't know 私は知らない
    d. Slightly Disagree やや同意しない
    e. Disagree 同意しない

12. If you have to drive for several hours, with few or no breaks from driving, do you feel drowsy or sleepy?

    あなたは数時間に運転する必要がある場合に運転してから休憩が短期間または全くない時に、眠気を感じますか？

    a. Agree 同意する
    b. Slightly Agree やや同意
    c. I don't know 私は知らない
    d. Slightly Disagree やや同意しない
    e. Disagree 同意しない

13. If you have to drive for several hours, with few or no breaks from driving, do you feel it is more difficult to judge your speed?

あなたは数時間に運転する必要がある場合に運転してから休憩が短期間または全くない時に、あなたの速度を判断することが困難だと思いますか？

a. Agree 同意する

b. Slightly Agree やや同意

c. I don't know 私は知らない

d. Slightly Disagree やや同意しない

e. Disagree 同意しない

14. If you have to drive for several hours, with few or no breaks from driving, do you feel it is more difficult to maintain your attention to road signs?

あなたは数時間に運転する必要がある場合に運転してから休憩が短期間または全くない時に、道路標識に注意を維持することがより困難であると思いますか？

a. Agree 同意する

b. Slightly Agree やや同意

c. I don't know 私は知らない

d. Slightly Disagree やや同意しない

e. Disagree 同意しない

No. 15-18, about participant opinion for vehicle safety system

15～18 番号、車両安全システムに関する参加者の考えについて

15. Have you heard about vehicle safety systems in vehicles such as ABS (Anti-Lock Brake System) or VSC (Vehicle Stability Control)?

    あなたは、アンチロック・ブレーキ・システム（Anti-Lock Brake System、略称：ABS）や車両安定制御システム（Vehicle Stability Control、略称：VSC）などの車両安全システムについて聞いたことがありますか？

    a. Yes　はい

    b. No　いいえ

note:

ABS (Anti-lock Brake System) was developed to reduce skidding and maintain steering control when brakes are used in an emergency situation.

注意：

アンチロック・ブレーキ・システム（Anti-Lock Brake System、略称：ABS）は、ブレーキが緊急事態で使用される場合、横滑りを低減し、操舵制御を維持するために開発された。

note:

VSC (Vehicle Stability Control) is a system that helps prevent side skids and help stabilize the vehicle while turning on a curve. When the vehicle senses a loss of traction or a slip, braking is automatically applied to all wheels and engine power is reduced to help secure the safety of the vehicle.

注意：

車両安定制御システム（Vehicle Stability Control、略称：VSC）は、カーブを曲がる時に起こりやすい横すべりを抑え、車両を安定化させるシステムです。車両はけん引力の損失またはスリップを検知すると、車両の安全性を確保するために、ブレーキが自動的に全ての車輪に適用され、およびエンジンのパワーが低減される。

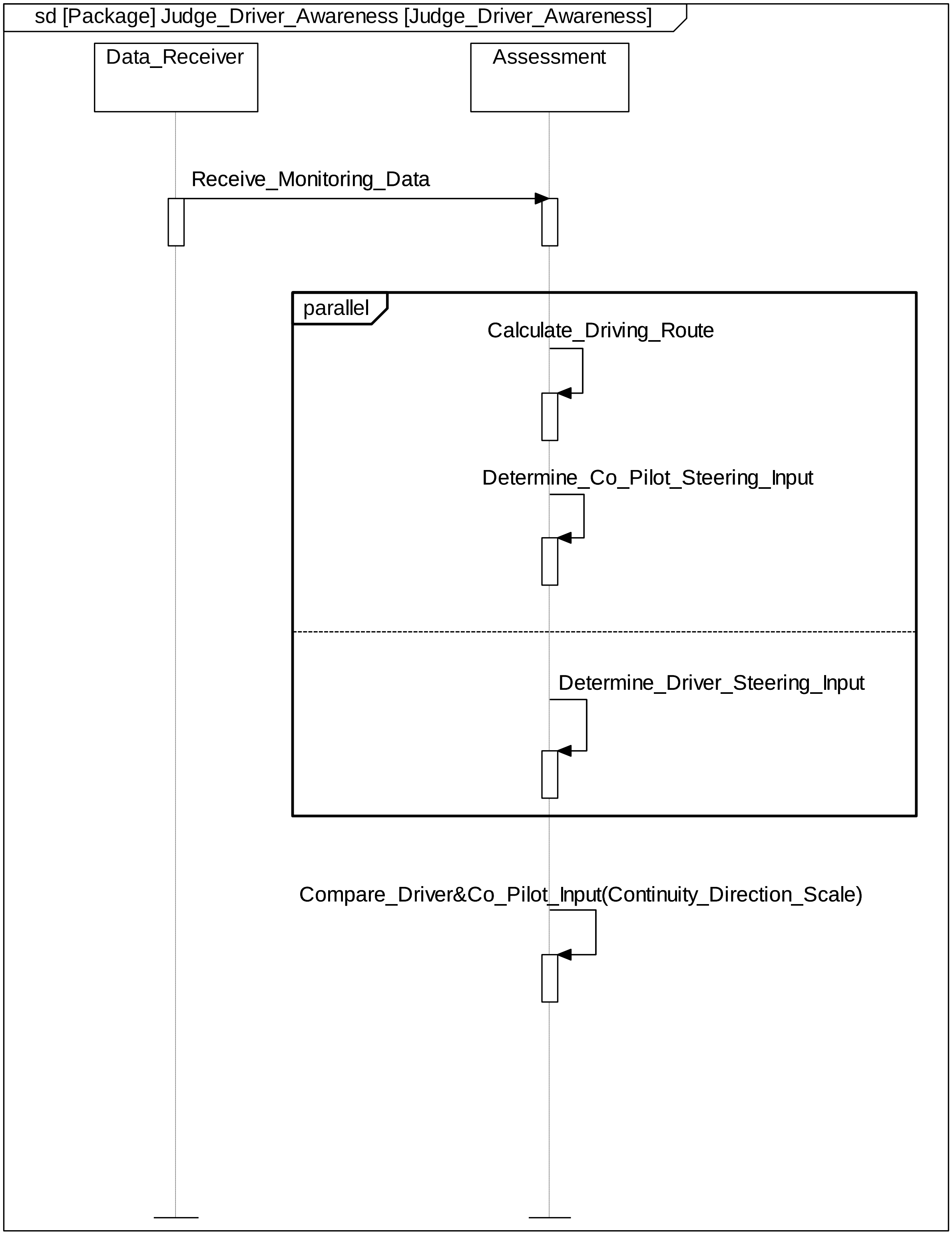
16. Do you think that if a vehicle is equipped with a Safety System (e.g. ABS, VSC), the possibility of an accident will reduce, even if the Driver is sleepy or distracted?
    あなたは、車両に安全システム（例えば、ABS、VSC）が装備されている場合、運転者が眠いまたは気を取られていても、事故の可能性が減少すると思いますか？
    a. Agree 同意する
    b. Slightly Agree やや同意
    c. I don’t know 私は知らない
    d. Slightly Disagree やや同意しない
    e. Disagree 同意しない

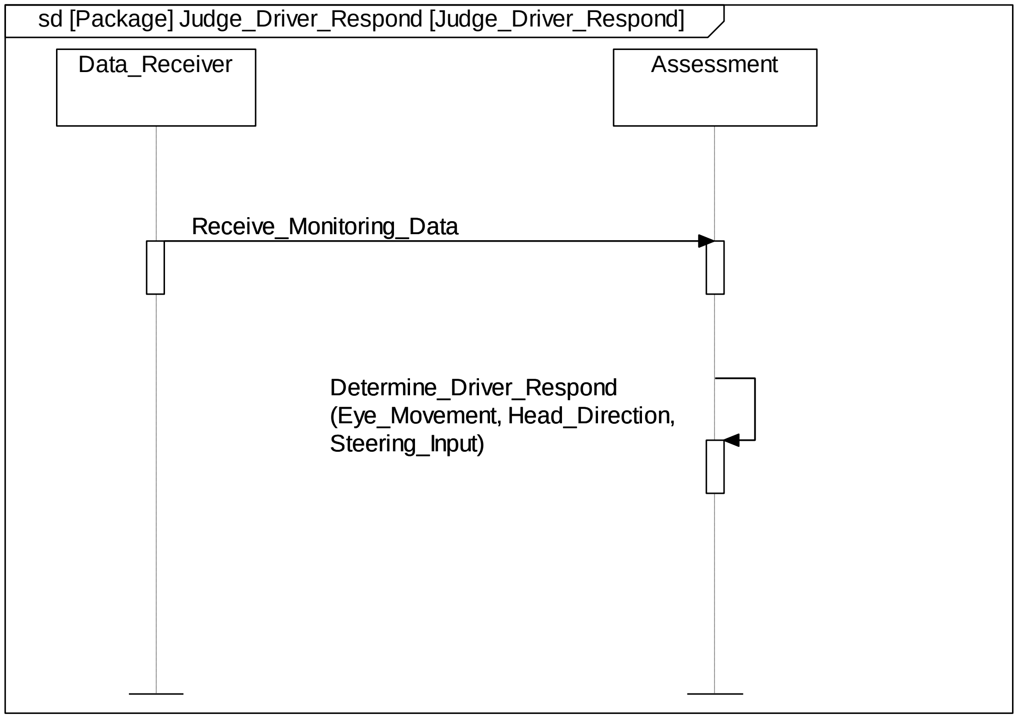
17. Do you think that it is necessary to create a Co-Pilot System that will monitor the status of the Driver (e.g. sleepy, distracted) and assist the Driver for controlling vehicle, in order to have a comprehensive safety system (Co-Pilot + Safety Systems) for mitigating accidents?
あなたは包括的な安全システム（副操縦士+安全システム）を持つために、副操縦士システムが必要だと思いますか。副操縦士システムは運転者の状態（例、眠気、気を取られること）を監視し、および車両の運転に運転者を支援します。
    a. Agree 同意する
    b. Slightly Agree やや同意
    c. I don’t know 私は知らない
    d. Slightly Disagree やや同意しない
    e. Disagree 同意しない
18. In your opinion, if there was a Co-Pilot System that monitored the Driver continuously during driving, would this system violate the driver's rights or restrict the driver’s freedom?
あなたの考えでは、ノンストップで運転者を監視する副操縦士システムがあった場合、このシステムは、運転者の人権を侵害し、または運転者の自由度を制限しますか？
    a. Agree 同意する
    b. Slightly Agree やや同意
    c. I don’t know 私は知らない
    d. Slightly Disagree やや同意しない
    e. Disagree 同意しない

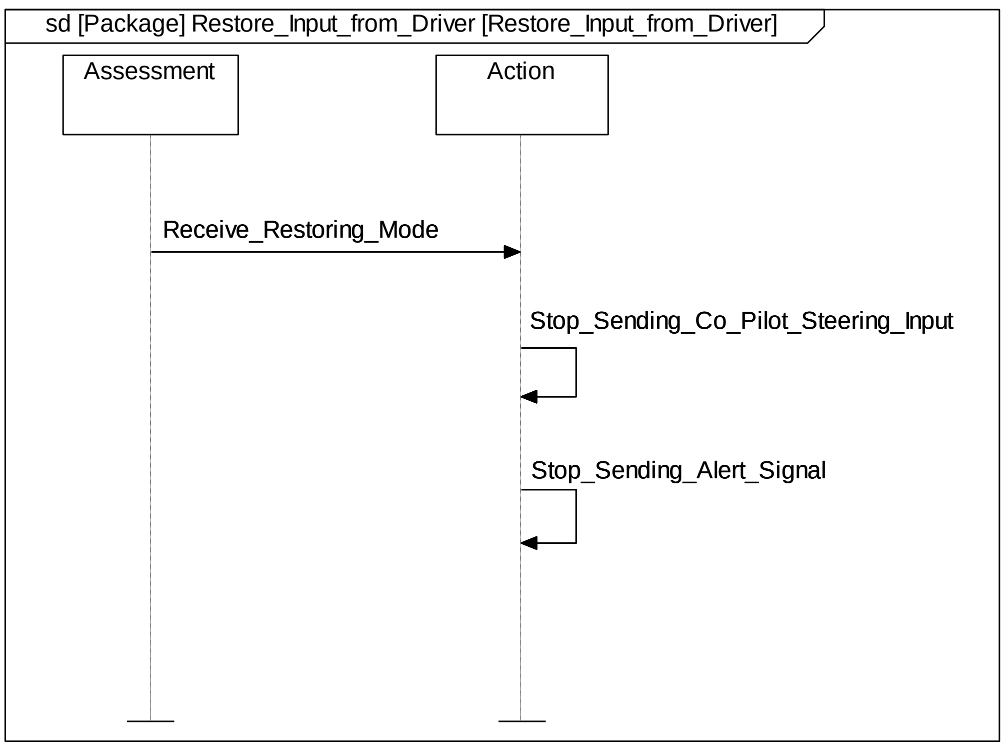
SESSION	TOPIC	NUMBER OF QUESTIONS
A	about participant background	7
B	about participant opinion for vehicle accident	3
C	about participant opinion for driver reliability	4
D	about participant opinion for vehicle safety system	4

SESSION	TOPIC	NUMBER OF QUESTIONS
A	参加者のバックグラウンドについて	7
B	車両事故に関する考えについて	3
C	運転者の信頼性に関する考えについて	4
D	車両安全システムに関する考えについて	4

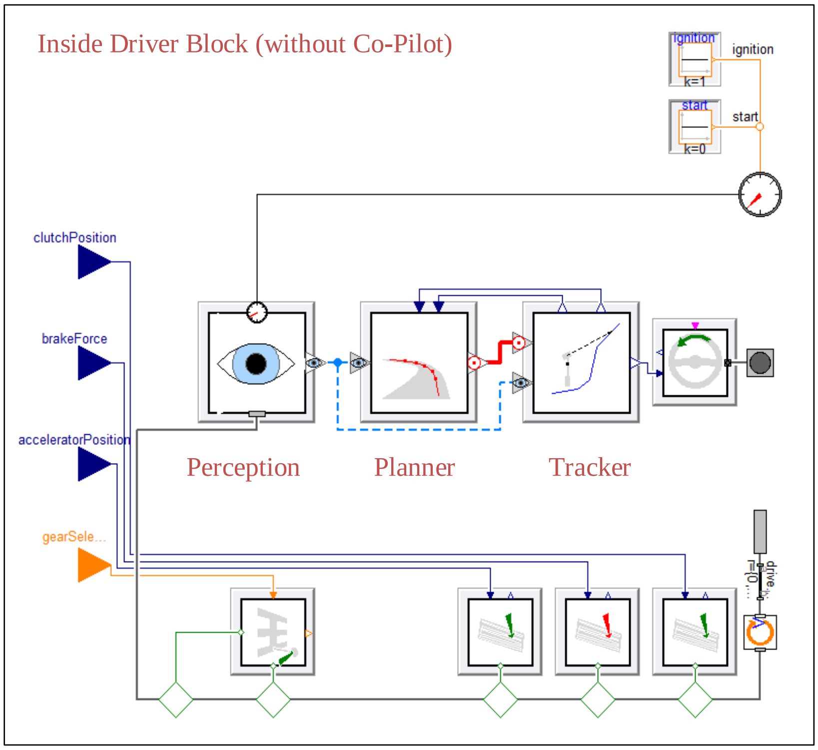
B. APPENDIX (CO-PILOT SYSTEM IN MBSE)

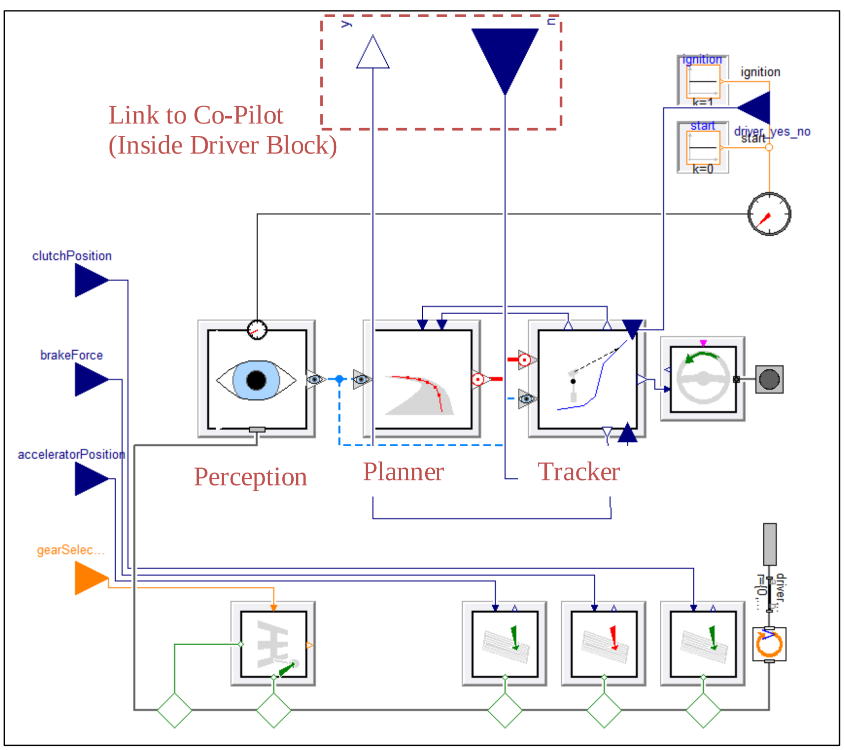


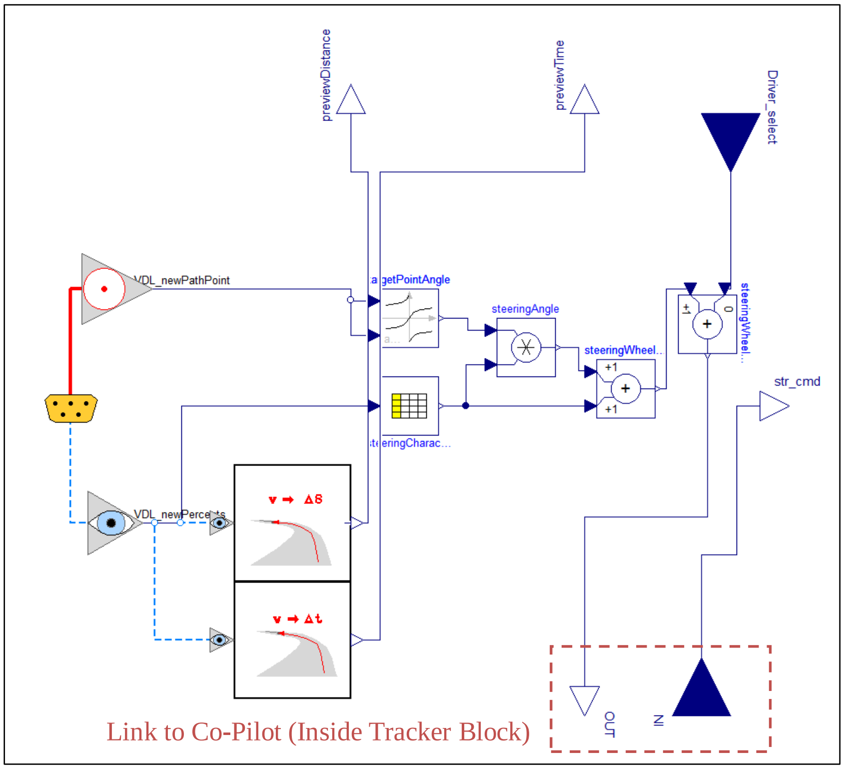

sd [Package] Judge_Driver_Respond [Judge_Driver_Respond]
Data_Receiver
Assessment
Receive_Monitoring_Data
Determine_Driver_Respond
(Eye_Movement, Head_Direction,
Steering_Input)


sd [Package] Restore_Input_from_Driver [Restore_Input_from_Driver]
Assessment
Action
Receive_Restoring_Mode
Stop_Sending_Co_Pilot_Steering_Input
Stop_Sending_Alert_Signal

C. APPENDIX (CO-PILOT SYSTEM IN DYMOLA)






previewDistance
previewTime
Driver_select
VDL_newPathPoint
steeringAngle
steeringWheel...
str_cmd
VDL_newPercepts
OUT
IN
Link to Co-Pilot (Inside Tracker Block)