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Modeling Of The Weight And Velocity Of Solid Waste Container Conveyed On A Sloppy Terrain

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***Abstract*— In this paper, modeling of the weight and velocity of solid waste container conveyed on a sloppy terrain is presented. The solid waste container has weight sensors and also velocity sensors installed at the four edges of the container. The velocity of the vehicle up the sloppy terrain is modelled along with the weight of the toxic container as the vehicle ascends up the sloppy terrain. The slope angle of the terrain is considered as a factor. The analytical expressions are also modelled in Simulink software and the used in the simulation of the parameters at different sloping angles. The results of the simulation on the sloppy terrain at slope angle of 3^0 show that in the four sensors, the vehicle velocity dropped from 25 km/hr to 8 km/hr within 60 seconds. In sensors 1 and 2 the weight increased to 8.5 tons whereas for sensors 3 and 4 the weight increased to 9.3 tons. The results at slope angle of 4^0 show that in the four sensors the velocity dropped from 25 km/hr to 8 km/hr within 60 seconds. In sensors 1 and 2 the weight increased to 8.5 tons whereas for sensors 3 and 4 the weight increased to 9.3 tons. The simulations were repeated for slope angles 5^0, 6^0 and 7^0 and the results show that the higher the slope angle, the lower the velocity and the lower the weight of the container in the front end sensors (sensors 1 and 2) but heavier the container weight at the backend sensors (sensors 3 and 4). The study gave useful insight for the design of anti-tampering mechanism which relies on weight variations of the toxic weight container as key parameter. In this case, the results show that there could be some instances of weight variations that do not amount to tampering of the solid waste in the container.**

Keywords*— Anti-Tampering Mechanism, Sloppy Terrain Motion, Waste Disposal Management System, Solid Toxic Waste Disposal, Tampering Monitoring Mechanism

1. INTRODUCTION

Today, advancements in technologies like wireless communication, electronic or internet-ready sensor and artificial intelligence have contributed immensely to the rapidly growing smart systems and Internet of Things (IoT) applications [1,2,3]. The application of these technologies has extended to waste disposal management system. Some researchers have examined the application of IoT in the monitoring of waste dumpsites and dump bins [4,5,6]. Specifically, some works have been presented on how to use wireless sensor to remotely monitor dump bins to determine when they are filled up so that the pick-up vehicles will only go to the dumpsite when the dump bins are filled [7,8]. Such approach minimize the time and fuel used to pick up or empty the waste bins [9,10].

Other technology based solutions have also focused on issues like optimal placement of dump bins in a given community, mapped-based solutions for minimizing time and resources used in emptying the waste bins in given community [1,12,13]. However, in this paper, the focus is on the monitoring of tampering of toxic waste while on transit from the source to the destination point. Specifically, the system works by using sensors to capture the waste container weight and velocity. The weight and velocity parameters are then fed into the waste management system which used special computer algorithm to assess the variations in the values of those parameters and then determine if tampering incidence has occurred.

Generally, variations in the waste container weight can suggest the incidence of tampering. However, it is known that the variations in the speed and acceleration of the waste container vehicle can result in the variation in the weight of the waste container. Such changes in the acceleration of the vehicle can occur when the vehicle is ascending a sloppy terrain and also when the vehicle is descending a sloppy terrain. Such variation in weight may not amount to tampering of the waste. As such, this paper focus on modeling the variations in the wight and velocity of the vehicle under the condition of motion on sloppy terrain. The models will help in the design of tampering monitoring system to avoid false tampering alarm.

2. METHODOLOGY

The model for characterizing the velocity and weight of the toxic waste container during motion on the sloppy terrain is meant to evaluate these parameters and how they vary with varying slop angles and speed. This becomes essential as the models will facilitate the development of anti-tampering system for smart waste disposal management system.

2.1 Analytical modeling of the motion on the sloppy terrain

The solid waste container has weight sensors and also velocity sensors installed at the four edges of the container. The velocity of the vehicle up and down of the terrain is determined and the weight of the toxic container on the terrain is obtained in this section. The effect of split angle is not considered. The weight of the toxic waste container for vehicle W_{Tu} climbing up the slope in sensors 1 and 2 is given as;

$$W_{Tu1,2} = W_n - (F_{dR} A_i S_H \emptyset)t \tag{1}$$

The weight of the container from sensors 3 and 4 is given as;

$$W_{Tu3,4} = W_{Tu1,2} + (F_{dR} A_i S_H \emptyset)t \tag{2}$$

Where F_{dR} represents the drag force, A_i represents the terrain slope angle increase per second, $\emptyset$ represents the slope angle and S_H represents the slant height of the terrain. The velocity of the truck up the terrain V_{Tu} is shown in the Equation below;

$$V_{Tu} = \frac{W_{T1,2} + W_{T3,4}}{0.7 S_H} \frac{1}{A_i} \frac{1}{t} \tag{3}$$

Where the V_T is the velocity of the up slope terrain. The weight of the container W_{Td} from sensors 1 and 2 for motion down the slope is given as;

$$W_{Td1,2} = W_{Tu1,2} \left(\frac{\emptyset W_n}{A_i S_H} \frac{1}{t} \right) \tag{4}$$

Then weight from sensors 3 and 4 for motion down the slope is given as;

$$W_{Td3,4} = \frac{\emptyset W_{Td1,2}}{t A_i} \tag{5}$$

The velocity of the truck during motion down the slope is given as;

$$V_{Td} = (V_n + V_{Tu}) \emptyset A_i t \tag{6}$$

The maximum tolerable slope angle according to US road supervisory body is 6% (with 7% allowed for mountainous areas. The slope angle utilized for the modeling were 3^0 , 4^0 , 5^0 , 6^0 , 7^0 and the velocity and weight of the containers were presented in chapter four.

3. RESULTS AND DISCUSSION

4.3 Results of the motion of the Truck in Sloppy Terrain

Results on the velocity and weight on the sloppy terrain:

The velocity of the vehicle on the sloppy terrain at slope angle of 3^0 is shown in the Figures 1 for sensors 1 and 2. The velocity of the vehicle on the sloppy terrain at slope angle of 3^0 is shown in the Figures 2 for sensors 3 and 4. In the four sensors the velocity dropped from 25 km/hr to 8 km/hr within 60 seconds.

Again, the weight of the waste container on the sloppy terrain at slope angle of 3^0 is shown in the Figures 3 for sensors 1 and 2. The weight of the waste container on the sloppy terrain at slope angle of 3^0 is shown in the Figures 4 for sensors 3 and 4. In sensors 1and 2 the weight increased to 8.5 tons whereas for sensors 3 and 4 the weight increased to 9.3 tons.

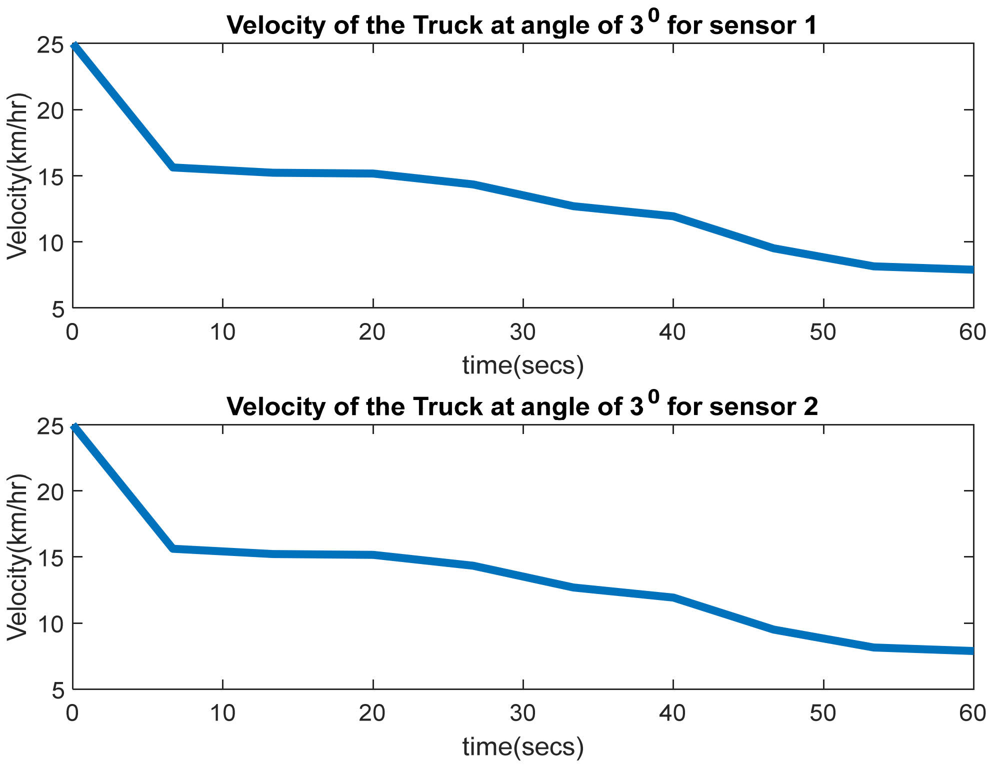

Figure 1, The velocity from sensors 1 and 2 at slope terrain angle of 3^0

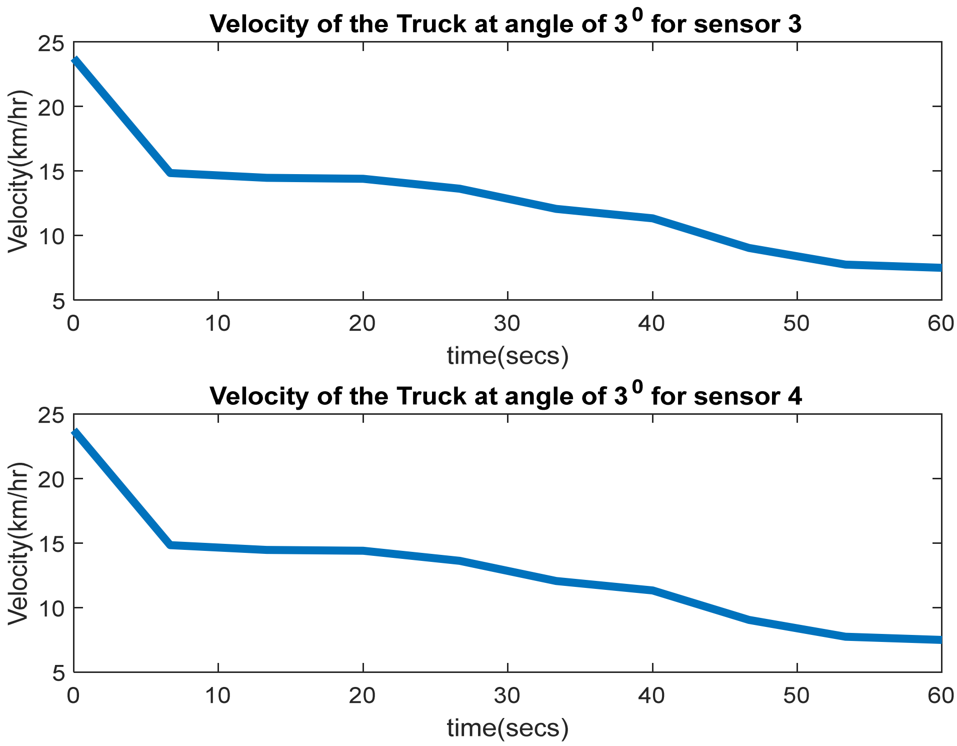

Figure 2, The velocity from sensors 3 and 4 at slope terrain angle of 3^0

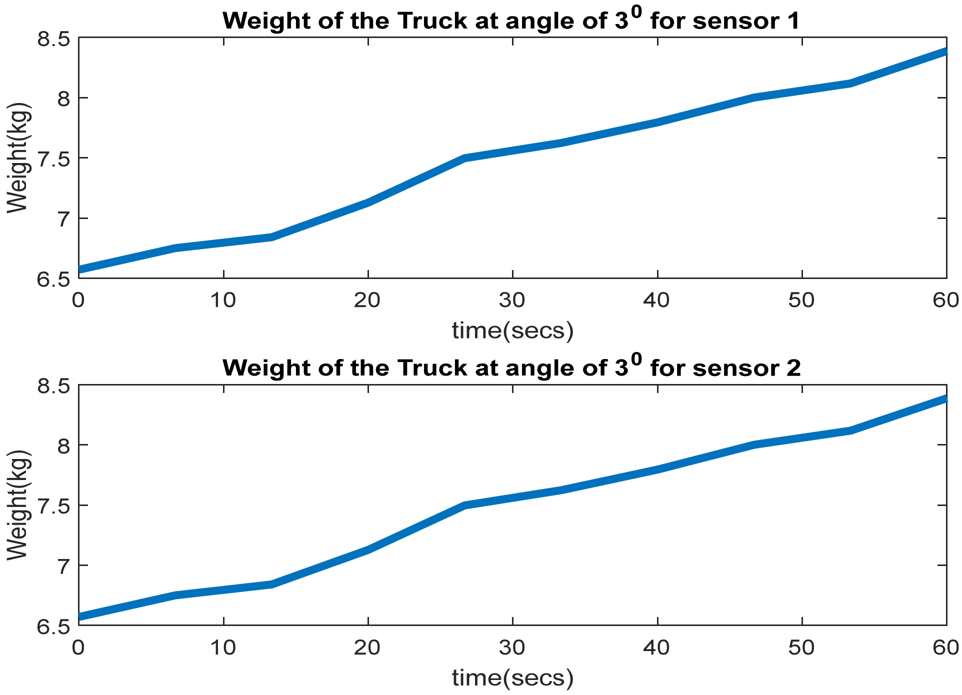

Figure 3, The weight from sensors 1 and 2 at slope terrain angle of 3^0

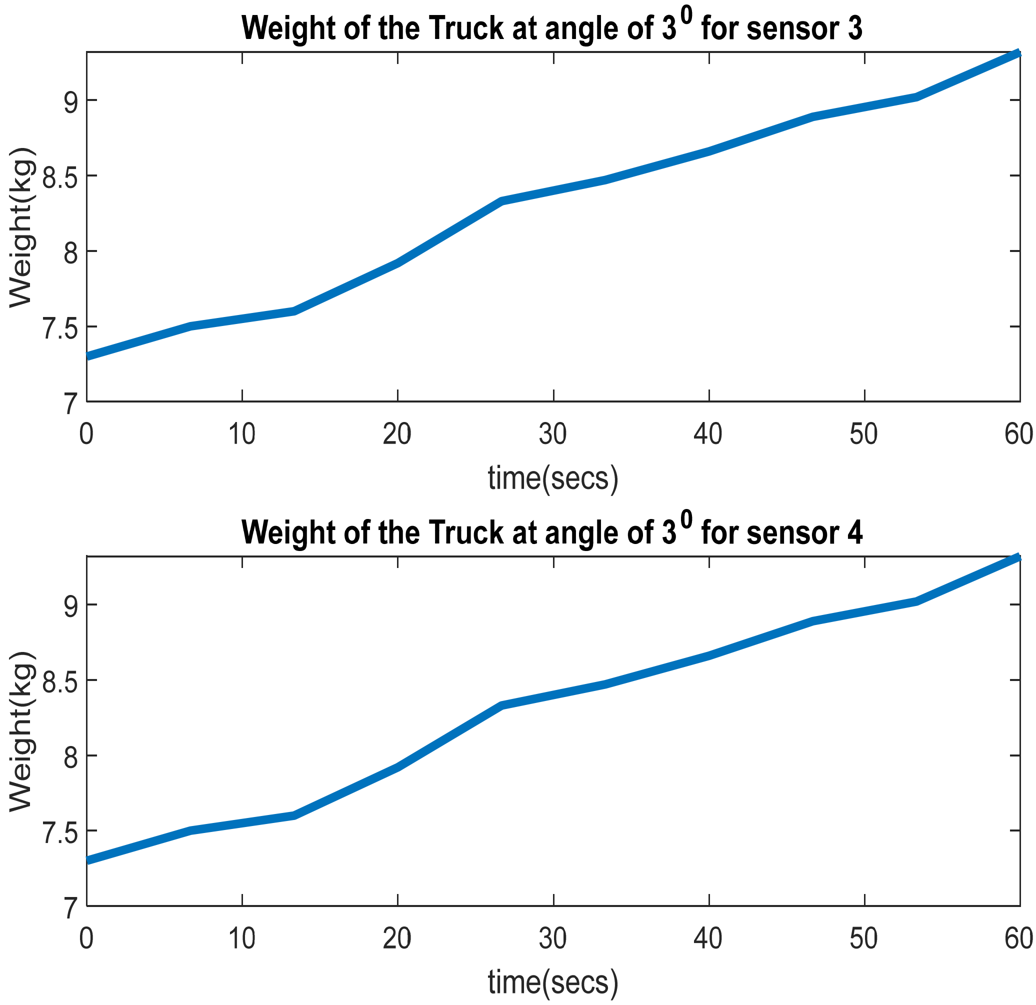

Figure 4, The weight from sensors 3 and 4 at slope terrain angle of 3^0

The velocity of the vehicle on the sloppy terrain at slope angle of 4^0 is shown in the Figures 5 for sensors 1 and 2.

The velocity of the vehicle on the sloppy terrain at slope angle of 4^0 is shown in the Figures 6 for sensors 3 and 4. In the four sensors the velocity dropped from 25 km/hr to 8 km/hr within 60 seconds.

Again, the weight of the waste container on the sloppy terrain at slope angle of 4^0 is shown in the Figures 7 for sensors 1 and 2. The weight of the waste container on the sloppy terrain at slope angle of 4^0 is shown in the Figures 8 for sensors 3 and 4. In sensors 1and 2 the weight increased to 8.5 tons whereas for sensors 3 and 4 the weight increased to 9.3 tons.

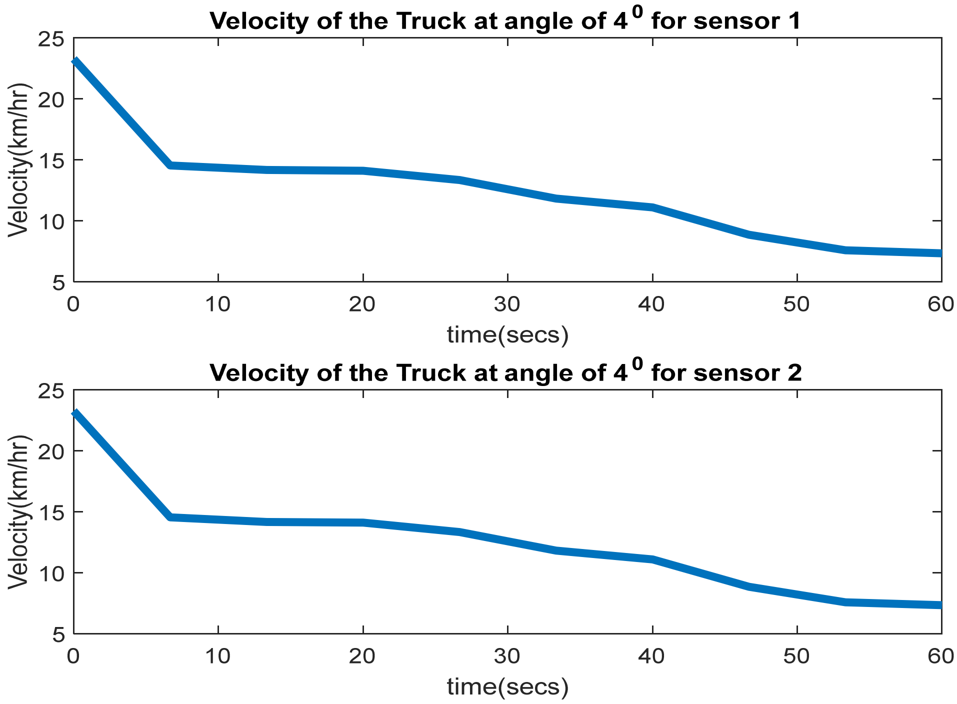

Figure 5, Velocity from sensors 1 and 2 at slope terrain angle of 4^0

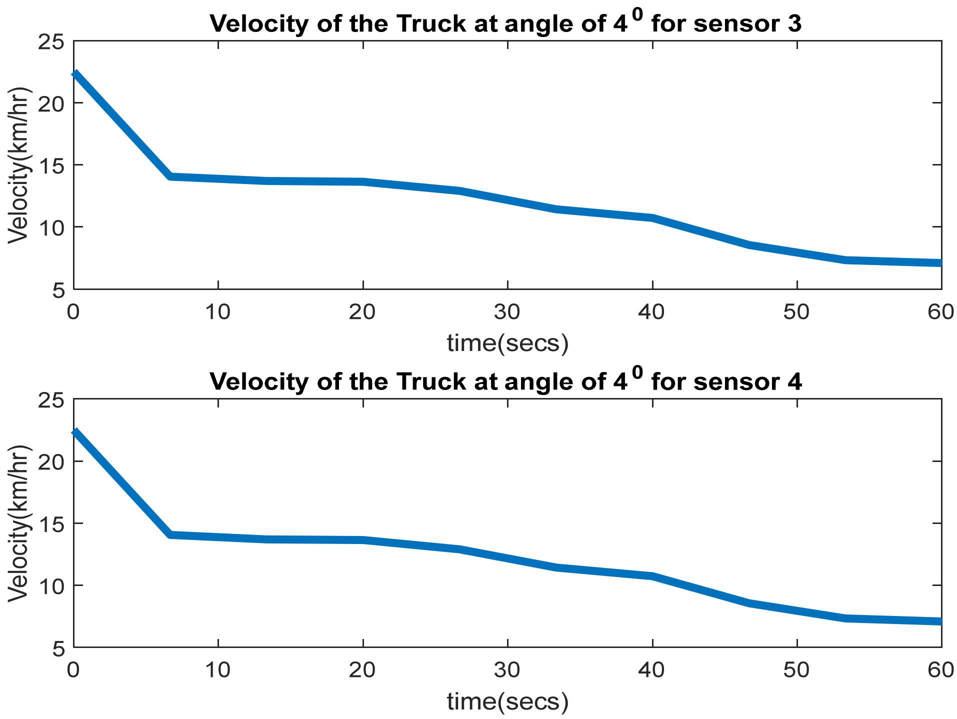

Figure 6, Velocity from sensors 3 and 4 at slope terrain angle of 4^0

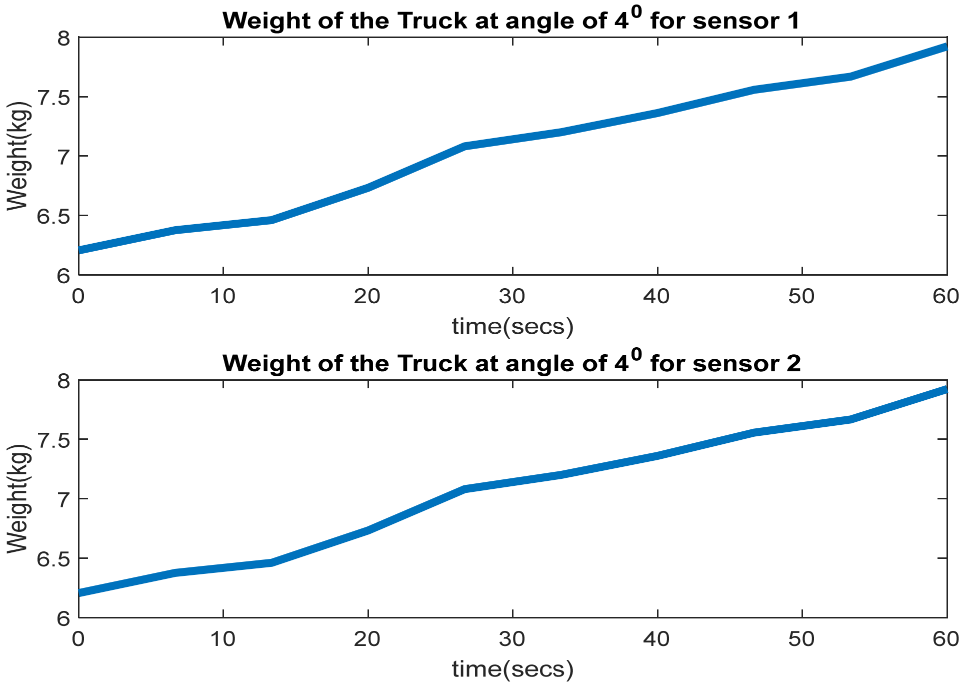

Figure 7, Weight from sensors 1 and 2 at slope terrain angle of 4^0

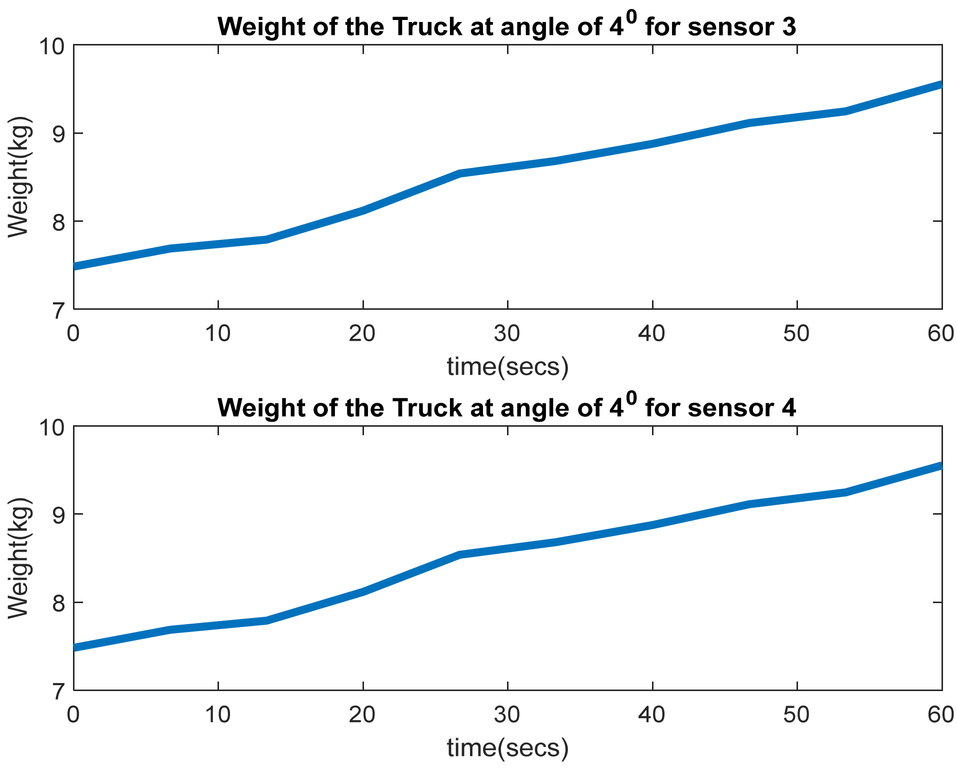

Figure 8, Weight from sensors 3 and 4 at slope terrain angle of 4^0

The velocity of the vehicle on the sloppy terrain at slope angle of 5^0 is shown in the Figure 9 for sensors 1 and 2. The velocity of the vehicle on the sloppy terrain at slope angle of 5^0 is shown in the Figures 10 for sensors 3 and 4.

Again, the weight of the waste container on the sloppy terrain at slope angle of 5^0 is shown in the Figures 11 for sensors 1 and 2. The weight of the waste container on the sloppy terrain at slope angle of 5^0 is shown in the Figures 12 for sensors 3 and 4.

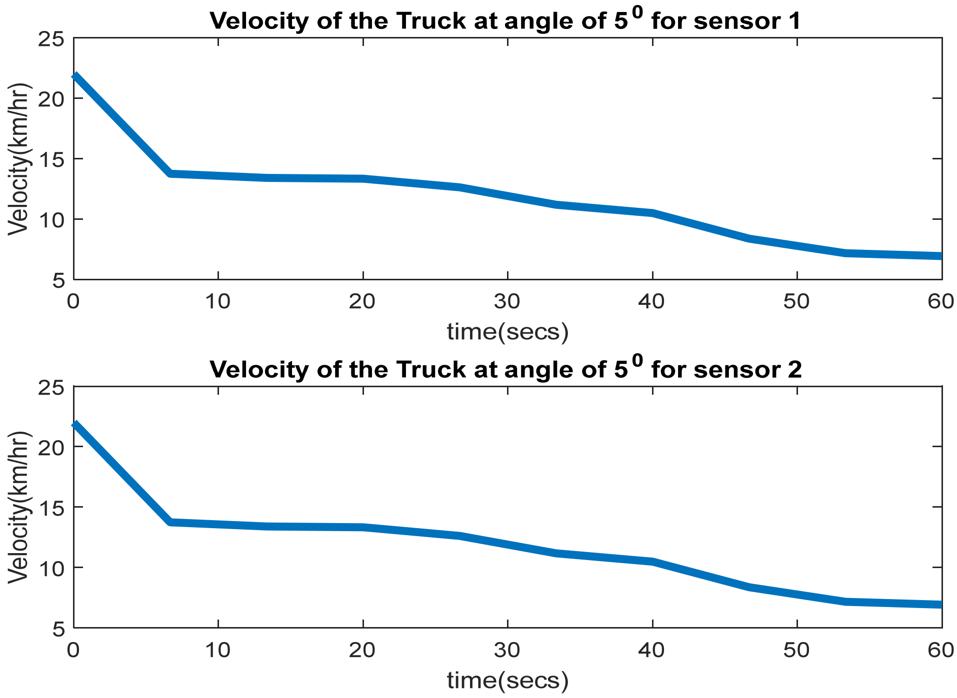

Figure 9, Velocity from sensors 1 and 2 at slope terrain angle of 5^0

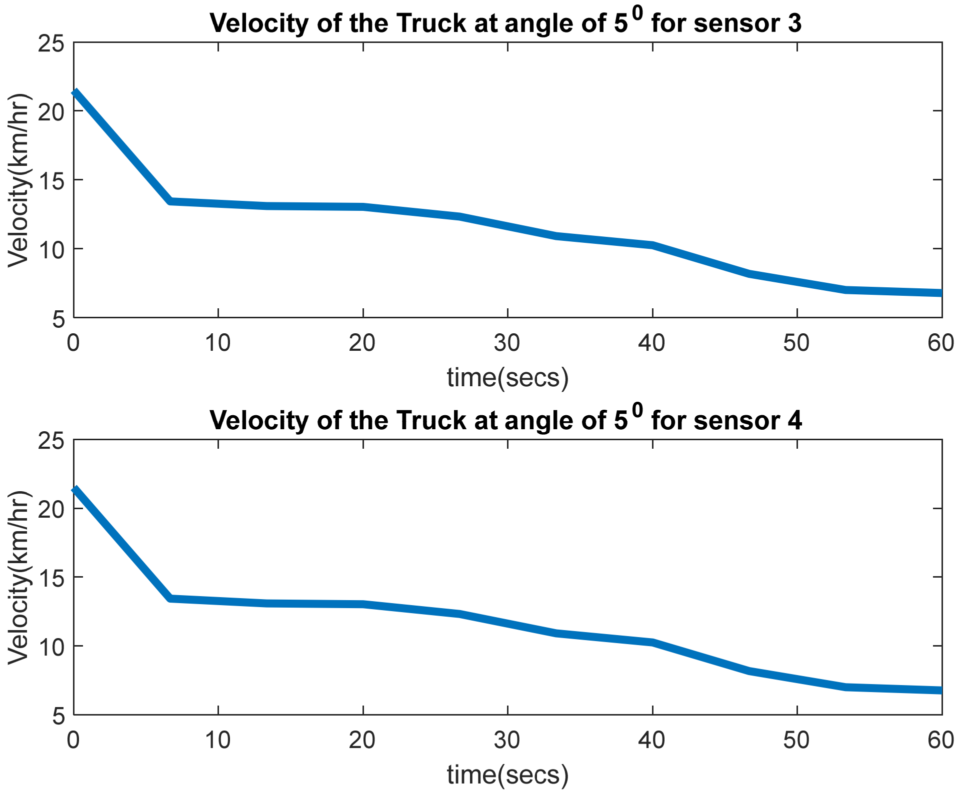

Figure 10, Velocity from sensors 3 and 4 at slope terrain angle of 5^0

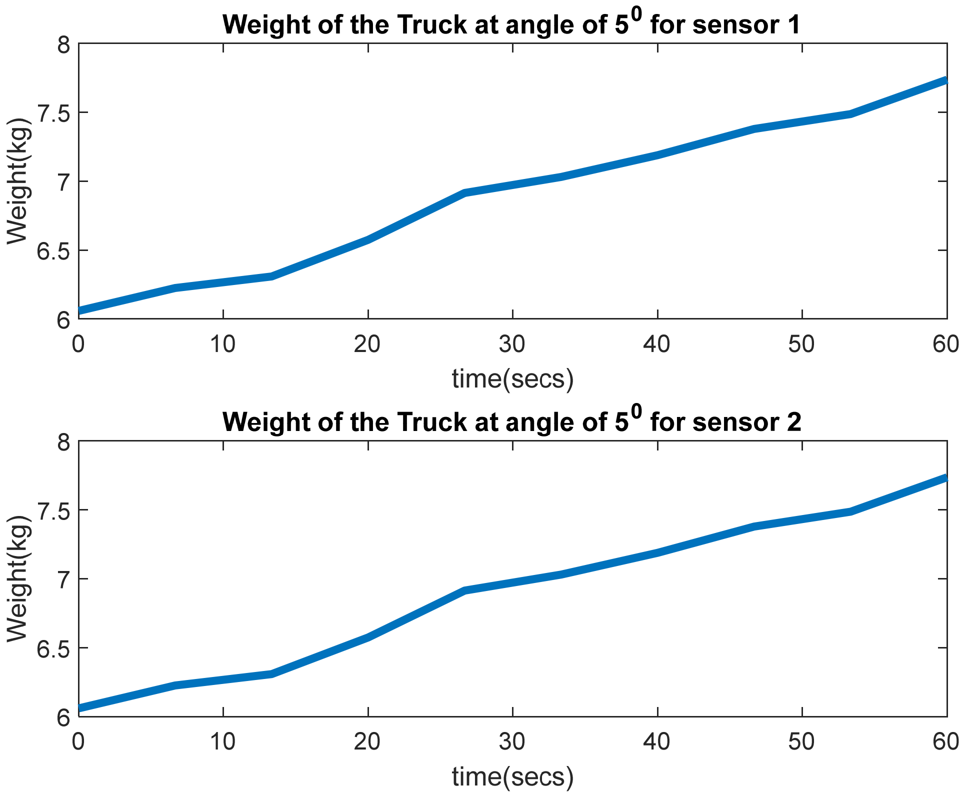

Figure 11, Weight from sensors 1 and 2 at slope terrain angle of 5^0

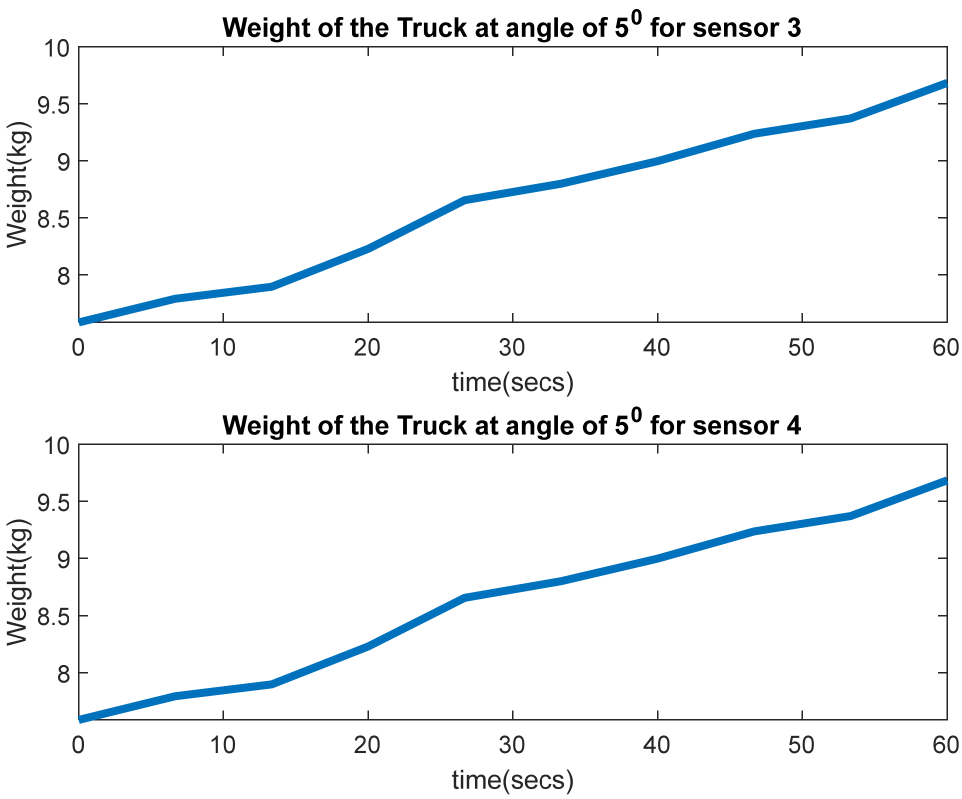

Figure 12, Weight from sensors 3 and 4 at slope terrain angle of 5^0

The velocity of the vehicle on the sloppy terrain at slope angle of 6^0 is shown in the Figures 13 for sensors 1 and 2. The velocity of the vehicle on the sloppy terrain at slope angle of 6^0 is shown in the Figures 14 for sensors 3 and 4.

In the four sensors the velocity dropped from 25 km/hr to 8 km/hr within 60 seconds.

Again, the weight of the waste container on the sloppy terrain at slope angle of 6^0 is shown in the Figures 15 for sensors 1 and 2. The weight of the waste container on the sloppy terrain at slope angle of 6^0 is shown in the Figures

16 for sensors 3 and 4. In sensors 1and 2 the weight increased to 6.7 tons whereas for sensors 3 and 4 the weight increased to 10 tons.

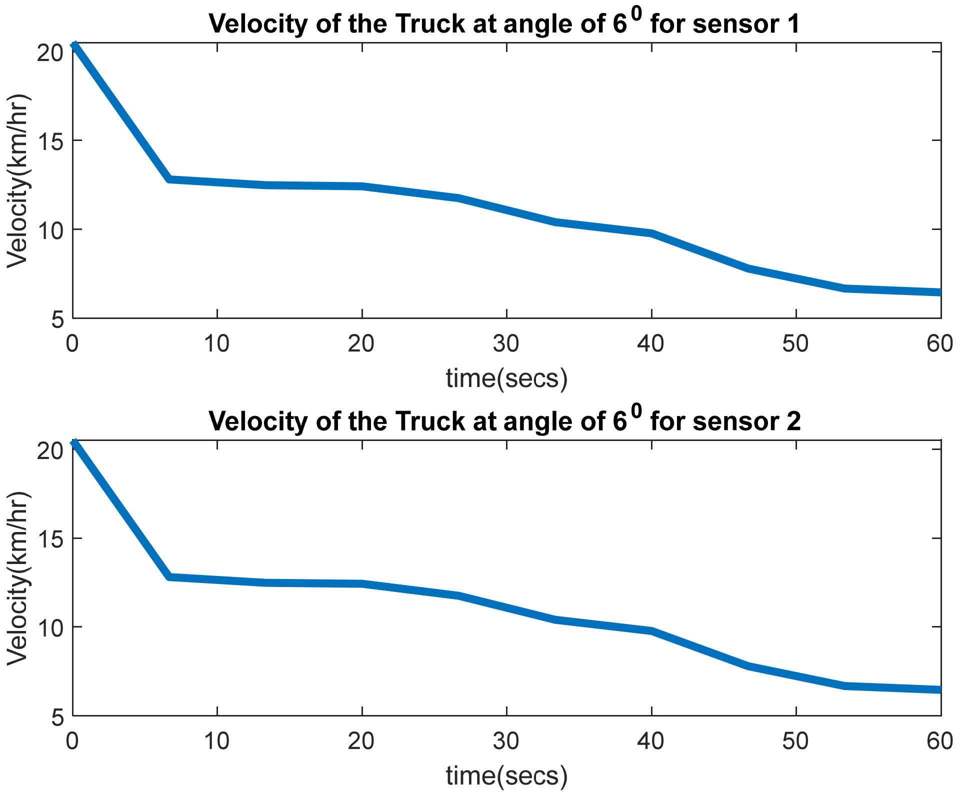

Figure 13, velocity from sensors 1 and 2 at slope terrain angle of 6^0

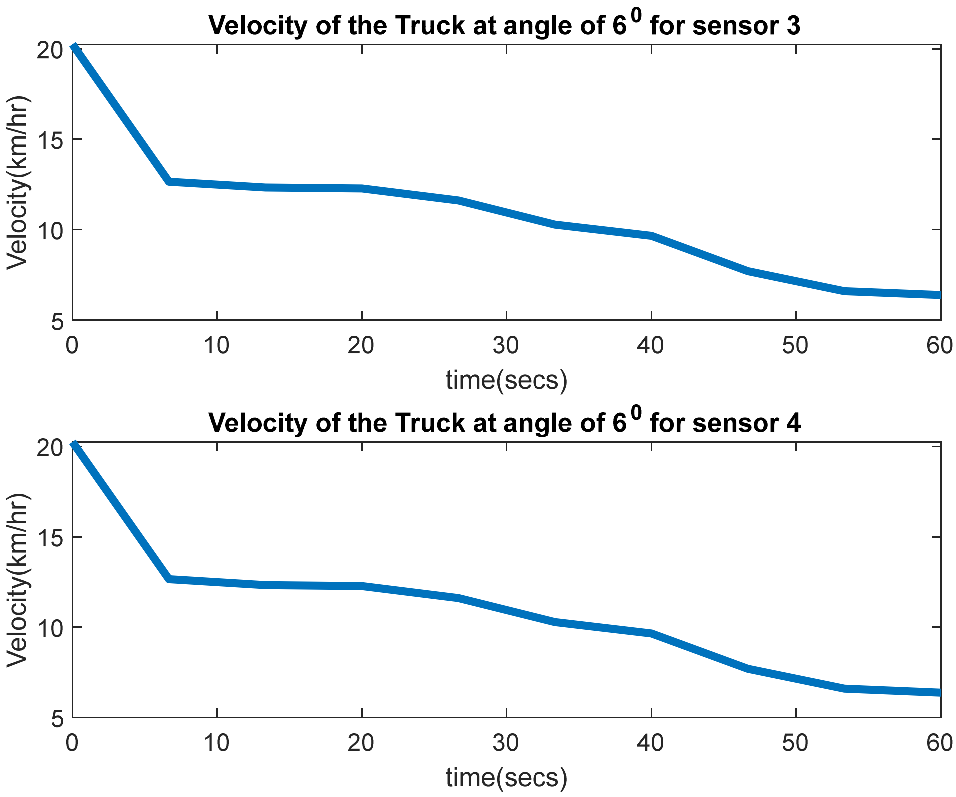

Figure 14, velocity from sensors 3 and 4 at slope terrain angle of 6^0

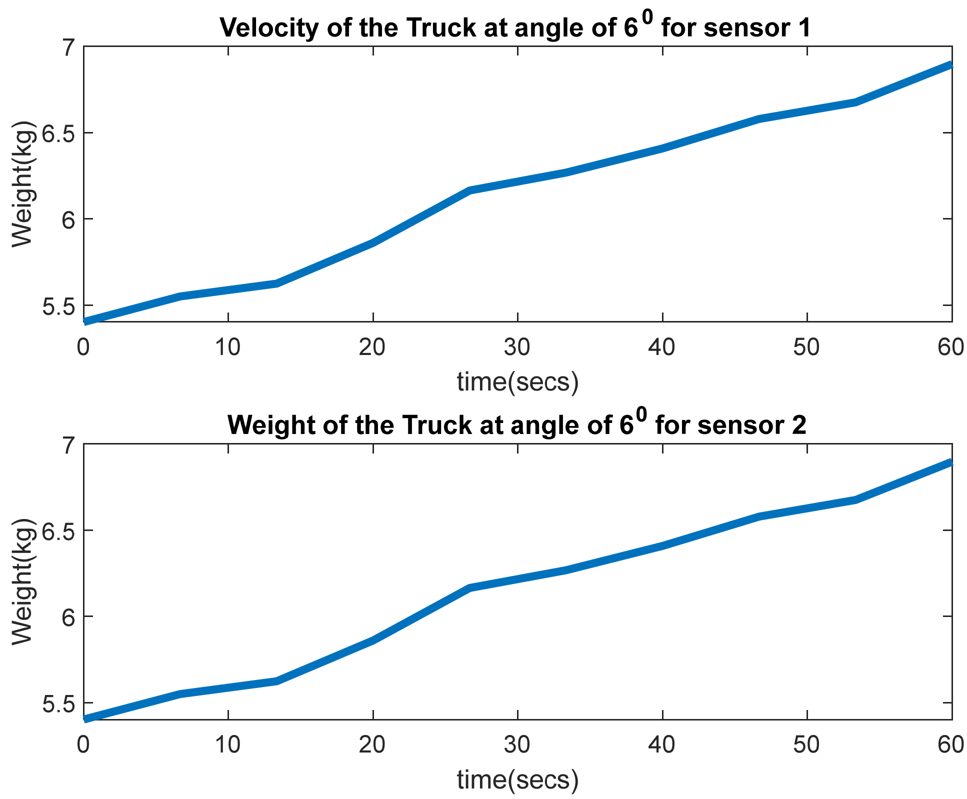

Figure 15, Weight from sensors 1 and 2 at slope terrain angle of 6^0

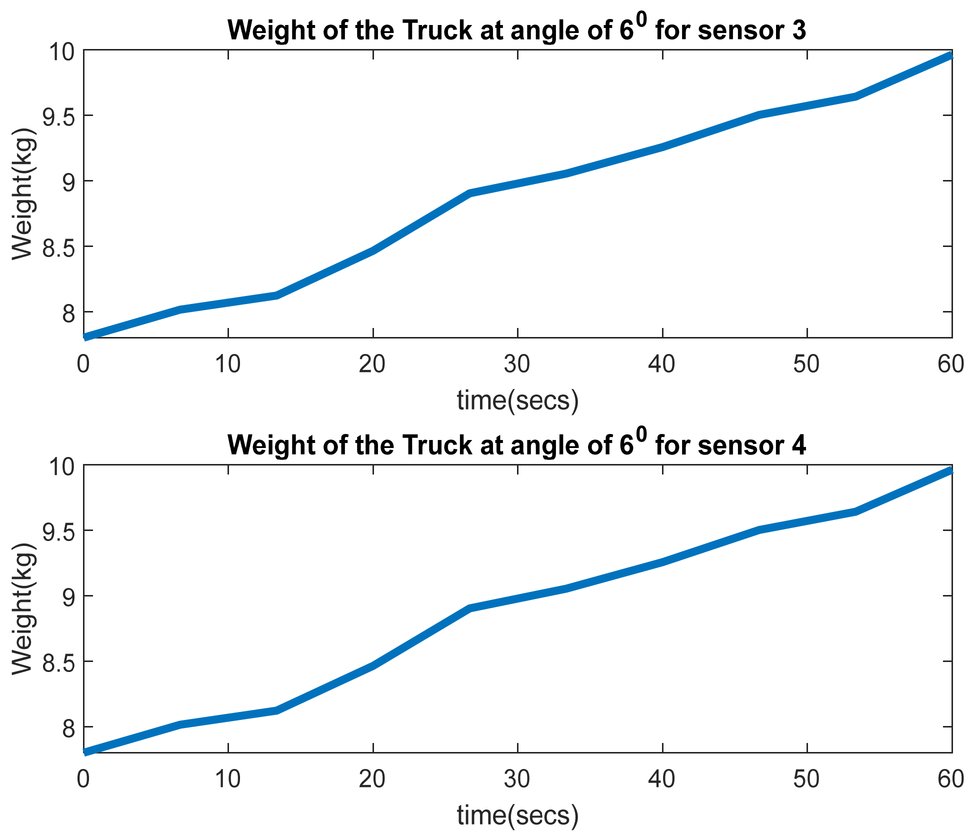

Figure 16, Weight from sensors 3 and 4 at slope terrain angle of 6^0

The velocity of the vehicle on the sloppy terrain at slope angle of 7^0 is shown in the Figures 17 for sensors 1 and 2. The velocity of the vehicle on the sloppy terrain at slope angle of 7^0 is shown in the Figures 18 for sensors 3 and 4. In the four sensors the velocity dropped from 25 km/hr to 8 km/hr within 60 seconds.

Again, the weight of the waste container on the sloppy terrain at slope angle of 7^0 is shown in the Figures 19 for sensors 1 and 2. The weight of the waste container on the sloppy terrain at slope angle of 7^0 is shown in the Figures 20 for sensors 3 and 4. In sensors 1and 2 the weight increased to 6.7 tons whereas for sensors 3 and 4 the weight increased to 10 tons.

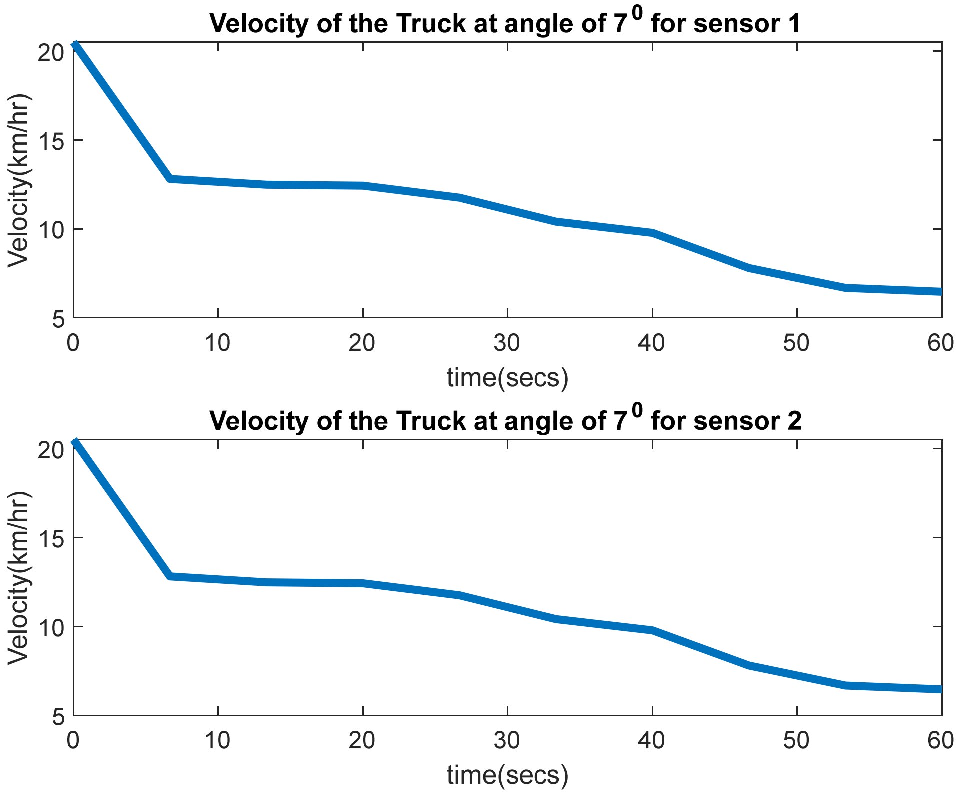

Figure 17, velocity from sensors 1 and 2 at slope terrain angle of 7^0

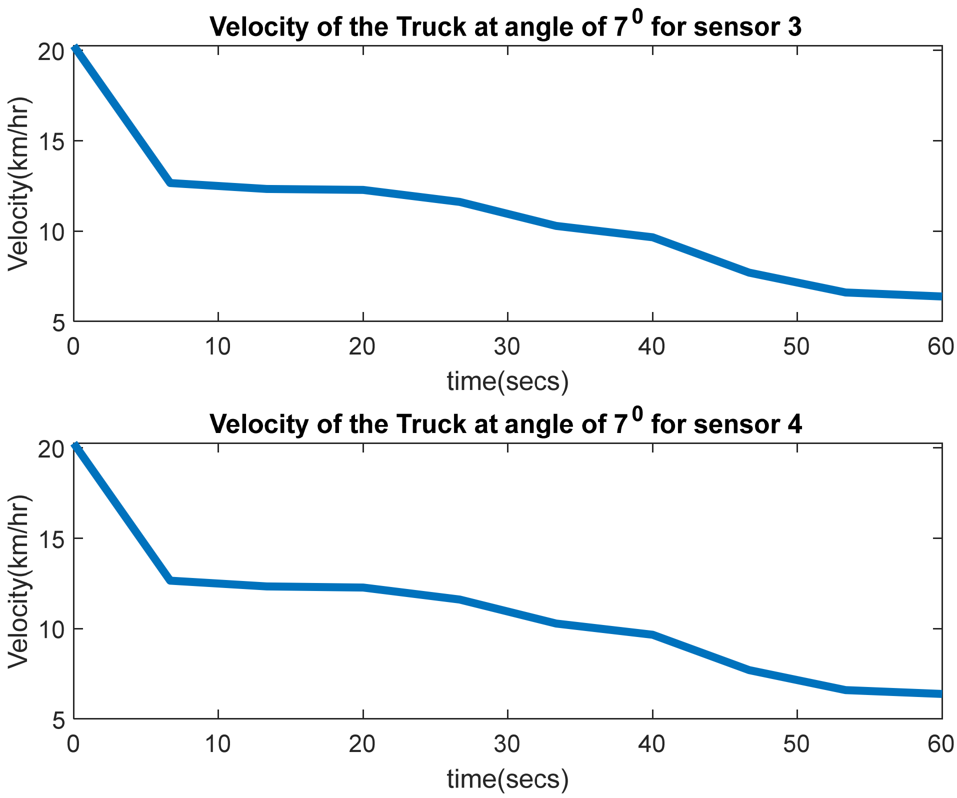

Figure 18, velocity from sensors 3 and 4 at slope terrain angle of 7^0

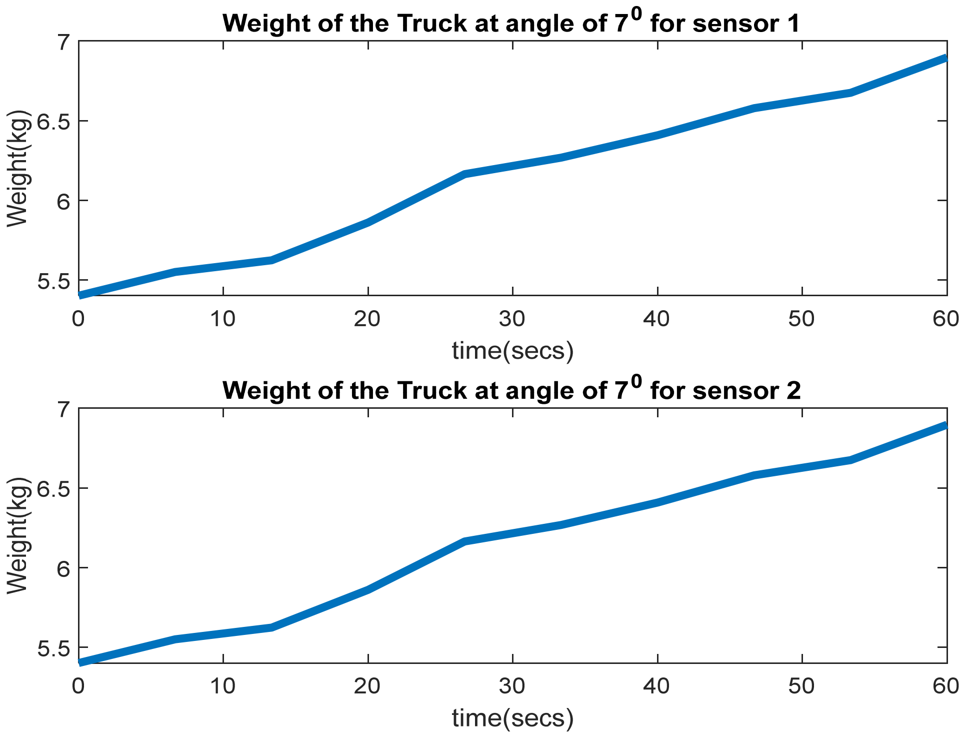

Figure 19, Weight from sensors 1 and 2 at slope terrain angle of 7^0

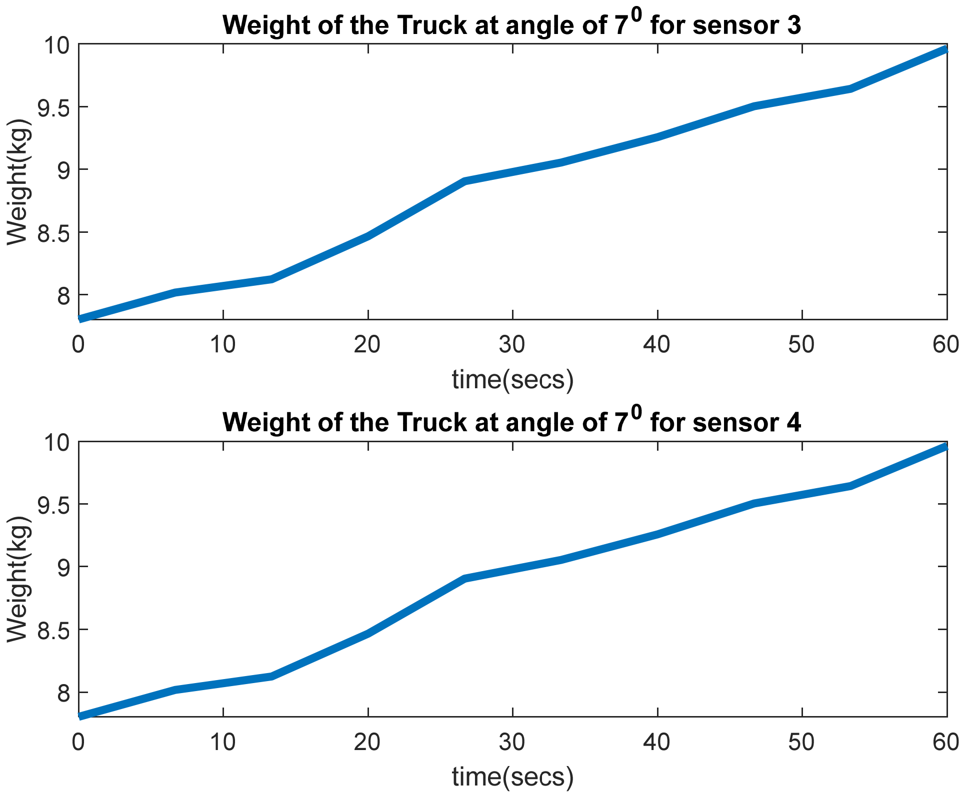

Figure 20, Weight from sensors 3 and 4 at slope terrain angle of 7^0

From the results displayed for the weight of the toxic container and the velocity of the truck, it is observed that the higher the slope angle, the lower the velocity and the lower the weight of the container in the front end sensors (sensors 1 and 2) but heavier the container at the backend sensors (sensors 3 and 4)

4. CONCLUSION

Evaluation of the weight of toxic waste container and the velocity of the vehicle conveying the container on a sloppy terrain is presented. The study considered only the vehicular movement up a sloppy terrain. Mathematical expressions for the container weight variations and vehicular velocity variations on ascending the sloppy terrain at different slopping angles are considered, in all the results show that the weight at the four sensors vary differently. Notably, it is observed that the higher the slope angle, the lower the velocity and the lower the weight of the container in the front end sensors (sensors 1 and 2) but heavier the container at the backend sensors (sensors 3 and 4). The study is useful in the development of toxic waste disposal management system with mechanism for monitoring tampering of the solid waste while being transported to the dump site.

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