Jurnal
Manajemen
Teknologi

**Jurnal Manajemen Teknologi, 22(2), 2023,135-148**
Available online at http://journal.sbm.itb.ac.id

# Iron Elbow and Straight-Chain Tool to Reduce Slip on Wood Transportation: An Experimental Study

**Yuniawati and Mutia Herni Ningrum***
Research Center for Biomass and Bioproduct,
Indonesian National Research and Innovation Agency, Jakarta

**Abstract.** *One of the obstacles in transporting wood is the occurrence of slippage. Slippage results in low productivity of timber transport with high production costs and soil damage. The research method is an experimental approach, namely designing, manufacturing and testing the supporting tools in the form of angle iron and straight iron chain. The research objective was to determine the effect of the use of assistive devices on slippage, productivity, wood transport costs and soil damage. The results showed that: 1). Tools from the wheelbarrows of the conveyance wheel from the straight iron chain of the slope class 0-8%, 9-15%, and 16-25% can minimize the occurrence of slippage higher than not using this tool, increase the wood transportation productivity, low transportation production costs, and minimize soil damage; 2). Elbow iron and straight-chain tools are the most efficient and effective. 3). The use of tools in the transportation of wood in slopes 0-8%, 9-15%, and 16-25% is recommended for smooth production.*

**Keywords:** *Iron elbow, straight chain, productivity, production cost, soil damage*

**Abstrak.** *Salah satu hambatan dalam pengangkutan kayu adalah terjadinya selip. Selip berakibat pada rendahnya produktivitas pengangkutan kayu dengan biaya produksi yang tinggi dan terjadinya kerusakan tanah. Metode penelitian adalah pendekatan eksperimen yaitu merancang, membuat dan uji coba alat bantu berupa besi siku dan rantai besi lurus. Tujuan penelitian adalah untuk mengetahui pengaruh penggunaan alat bantu terhadap selip, produktivitas, biaya pengangkutan kayu dan kerusakan tanah. Hasil penelitian menunjukkan bahwa : 1). Alat bantu dari sarung roda alat angkutan dari rantai besi lurus kelas kelerengan 0-8%, 9-15% dan 16-25% dapat meminimalkan terjadinya selip lebih tinggi daripada tidak menggunakan alat bantu, meningkatkan produktivitas pengangkutan kayu, biaya produksi pengangkutan rendah, dan meminimalkan kerusakan tanah; 2). Alat bantu dari besi siku dan rantai besi lurus paling efisien dan efektif; 3). Penggunaan alat bantu pada kegiatan pengangkutan kayu di kelerengan 0-8%, 9-15% dan 16-25% dianjurkan untuk kelancaran produksi.*

**Kata kunci:** *Besi siku, rantai lurus, produktivitas, biaya produksi, kerusakan tanah*

*Corresponding author. Email: mutiahernin@gmail.com
Received: May 31th, 2022; Revision: April 26th, 2023; Accepted: May 23th, 2023
Print ISSN: 1412-1700; Online ISSN: 2089-7928. DOI: http://dx.doi.org/10.12695/jmt.2023.22.2.2

## Introduction

To remove wood from the forest, it is necessary to transport wood. Extracting the wood from the forest requires timber transportation activities. Timber transportation is one of a series the timber harvesting activities. The purpose of transporting wood is that it can continuously arrive at its destination at the right time with minimal cost. This is appropriate Allman et al. (2021); British Columbia Forest Safety Council (2015); Koirala et al. (2017) transportation of timber from the forest to the processing facilities is a major component of forest operations. Logging trucks play a critical transportation role in moving logs. Without logging trucks, the forest industry would grind to a halt. Timber haulage is an important link in the raw timber supply chain, with substantial energy consumption and costs.

Timber transportation in plantation forests is generally used trucks. Trucks use rubber tires, which often have slippage problems, especially when operationalized on slippery dirt roads. That statement is supported by Hoever & Kropp (2015); Jansson (2022); Radite et al. (2008) research which explained that the rubber in the tires becomes stiffer and less elastic with time. The tire tread is the part of the rubber compound that makes contact with the surface during rotation. Tread depth is the distance between the deepest groove of the tire and the outermost part of the tire tread. The effect of tread depth on rolling resistance was dependent on surface texture. Trucks use rubber tires as a means of traction. Rubber traction tires have good traction but have the disadvantage of wearing out quickly.

According to Mirosław & Mirosław (2021), slips occur when the wheel rotates the new undistorted part of the tire enters into contact with the road and stops and keeps sticking to the road by the friction force between the tire and the road. Because the wheel is rotating, the part of the tire is deformed and transmits the force to the wheel rim. In the meantime, the deformed part of the tire carries out some part of the transmitted force. To keep the propelling force at a constant value, the balance of new and carried-out deformation must be ensured so the wheel is rotating faster than the axle of the wheel. Meanwhile, according to Salehi et al. (2020), tire grip results from the frictional forces generated under driving conditions such as cornering, braking, and accelerating, which are generated by the tire slipping on the contact patch. When the vehicle brakes, accelerates or corners, the tire tread elements in the contact area move with a marked displacement concerning the road, and it is called slippage.

The cause of slippage, according to Faizal (2014), is due to changes in the frictional force between the road and the wheels resulting in slippage. Slippage causes an obstacle to the truck's forward speed, where there is a very fast rotation of one of the truck's wheels which is not followed by the forward movement of the truck body. The greater the slippage that occurs, the less power is available to pull the vehicle forward. So to find out how much pulling force a vehicle can produce, it is necessary to know the traction coefficient.

Factors that cause skidding on truck tires according to Arina (2020); Kumar & Gupta (2021), are pavement surface, tire characteristics, and environmental-related parameters. Depending upon the rotational speed of the wheel and surface characteristics of the road surface, once the maximum friction is reached, the wheel may start skidding. Slippery surface conditions due to ice, snow or rain. Truck tires do not grip the road surface properly, damage to vehicle components such as worn tires and worn brakes, loss of traction on the front of the truck and locking of the truck's rear tires.

As a result of slippage, in addition to causing a decrease in productivity and an increase in production costs, it also causes soil damage in the form of rows or grooves along the tracks of truck tires, which can reduce the productivity of transportation activities and increase production costs.

According to Battiato et al. (2015), high slippage due to the pulling of truck tires causes damage to the upper layer of soil and forms a non-strong layer that is very susceptible to erosion, and the layers below which shear deformation contributes to changes in the functioning of the soil structure. Research results by Bulgakov et al. (2021), show that the maximum permitted amount of tractor wheel slip should not exceed 15%. With more slip, the soil structure deteriorates significantly.

The negative impacts caused by slippage in timber transport activities are low timber transport productivity, high production costs, and soil damage, which can cause delays in the smooth flow of timber production to reach consumers, resulting in cost and time losses for the company. Based on this, assistive device research is needed to reduce slippage, increase transport productivity, reduce production costs, and minimize soil damage. This paper aims to determine the effect of the use of assistive devices on slippage, productivity, production costs, and soil damage.

## Research Methodology

*Location and Time*

The research was conducted at RPH Maribaya, BKPH Parung Panjang, KPH Bogor, Perum Perhutani Unit III West Java & Banten. Administratively, the government is located in 3 (three) sub-districts, namely Tenjo, Jasinga, and Parung Panjang Districts. Meanwhile, the management boundaries of BKPH Parung Panjang are as follows:

- To the west, it borders KPH Banten
- To the south, it borders BKPH Jasinga
- To the east, it borders BKPH Leuwiliang
- To the north, it borders BKPH Tangerang

Geographically BKPH Parung Panjang is located at 106°26"03"BT to 106°35"16"BT and 06°20"59" to 06°27"01"LS. The forest area of BKPH Parung Panjang is designated as a Company Class (KP) *Acacia mangium* which is divided into 3 (three) Forest Management Resorts (RPH) covering an area of 5,397.24 ha, namely Tenjo RPH covering an area of 1,536.15 ha, Maribaya RPH covering an area of 2,127.39 ha and Jagabaya RPH covering an area of 1,733.70 ha. The forest area at BKPH Parung Panjang belongs to climate type A with an average rainfall of 3,000 mm/year, the highest daily temperature of 25.50°C, and the lowest 18°C based on the ratio of wet months to dry months each year. It has a field configuration that is mostly relatively flat to gentle, with the slope of the field varying from flat and rather steep.

*Materials*

The main materials in this study are an iron chain with a diameter of 15 mm, chainring length of 50 mm, chainring width of 30 mm, auxiliary tool length 5000 mm, elbow iron size 3 cm x 3 cm x 3 cm, welding wire, sackel, plastic mine, bolt, tinner, wood paint, iron paint, and brush. The tools used in this study are meters, time-measuring devices, and timber transport trucks.

*Research Procedure*

The research framework is presented in Figure 1.

1) Identification of the research problem is that the condition of the transportation road in the Perhutani area is still in the form of dirt, when it rains the ground becomes wet and slippery. This condition causes the truck when transporting wood to slip. As a result of this skid, effective time is lost, the production process is hampered, and fuel is wasted, resulting in low transportation productivity with high production costs. There needs to be a tool to reduce the skid by designing a tool mounted on the rear truck tire with a simple, easy, and cheap design.
2) The research plan is prepared after knowing the results of problem identification in the field by first developing ideas related to tools suitable for use in dirt road areas. The design of the auxiliary tool, a combination of angle iron and chain, is almost like a military steel tank capable of running in muddy and water road conditions.

3). The research aims to reduce slippage during timber transport to increase the productivity of timber transport and minimize production costs and soil damage.

4). The study aimed to determine the effect of assistive devices on slippage, productivity, wood transport costs, and soil damage. Using these tools is expected to expedite the production process of transporting wood.

5) Creation of a logging tool

The tool's design to reduce slippage on slippery soils can be seen in Figures 2 and 3. The specifications of the tool are:

a. The size of the elbow iron used to make the tool measures 3 cm x 3 cm x 3 cm.
b. The length of the auxiliary is 5 m.
c. The width of the chainring is 3 cm.
d. The length of the chainring is 5 cm.
e. The diameter of the chain is 1.5 cm.

6) Trial of the tool

The stages carried out are as follows (Yuniawati, 2015):

a. Deciding selected plots using a purposive technique represents the slippery conditions and set slopes.
b. Determining the treatment consists of two factors: the first is using a logging tool and the second one is slope variation (0-8%, 9-15%, 16-25%).
c. Each treatment with 5 tests on the condition of a loaded and non-loaded truck. So there will be 6 treatment combinations (2 x 3) and 30 data (6 treatments x 5 replays). The observed item is the volume of transported wood (m3), the length of the measuring plot (m), and the transport time on that measuring plot (second).
d. Carrying out observations and measurements of slippage on truck wheels. A chain attaching on a transport truck tire can be seen in Figure 3.
   - Marking the truck wheels using white paint. When the truck is running and the markings are touched on the ground or the auxiliary device is calculated the number of revolutions of the wheels.
   - Measuring the slip on the truck wheels through assistive devices by measuring the difference in the mileage of a truck without a load and a loaded truck at the same number of wheel revolutions.
   - Recording mileage, wood volume, travel time, and the number of wheel turnovers; Carrying out measurements of the wheel traction coefficient by recording the weight of the truck, truck specifications, and engine power; and carrying out observations of soil texture directly in the field by curling the soil using fingers and feeling the fine roughness of the soil particles.

7) Parameter Measurement

Parameter measurements include wheel slippage, wheel traction coefficient, transport productivity, transport production costs, and soil damage. The way the parameter is measured is explained below.

a. Truck wheel slippage: records the difference between the mileage of a truck without a load and a loaded one on the condition of the truck wheels through the auxiliary device.
b. Wheel traction coefficient: records the weight of the truck and the specifications of the truck.
c. Productivity: records working time, mileage, and wood volume.
d. Financial data: record the price of the means of transportation, the price of making auxiliary tools, truck working hours per day, capital interest, tax costs, insurance costs, equipment maintenance costs, fuel costs, oil and lubricant costs, and wage costs.
e. Soil damage: measures the depth of soil formed due to slippage on the left or right side of the truck tire.

8). Evaluation

The trial results of the tool are evaluated in terms of the slippage that occurs, the productivity of timber transport, production costs, and soil damage. Evaluation is carried out after the end of the research activity to find the strengths and weaknesses of the designed tools and trials.

The evaluation results found a weakness in the tool: the chain installation takes a few minutes, so future designs can add hook locks that make it easier to tie the chains to the tires. The advantage of the tool is that it is more efficient where slippage can be minimized so that the transportation production process runs smoothly. With these advantages, the tools from the results of this research contribute to the smooth production of timber transportation so that productivity increases, minimizing production costs and soil damage.

Secondary data collection includes the general state of the field, the general state of the company, and other supporting data quoted from the company and interviews with employees.

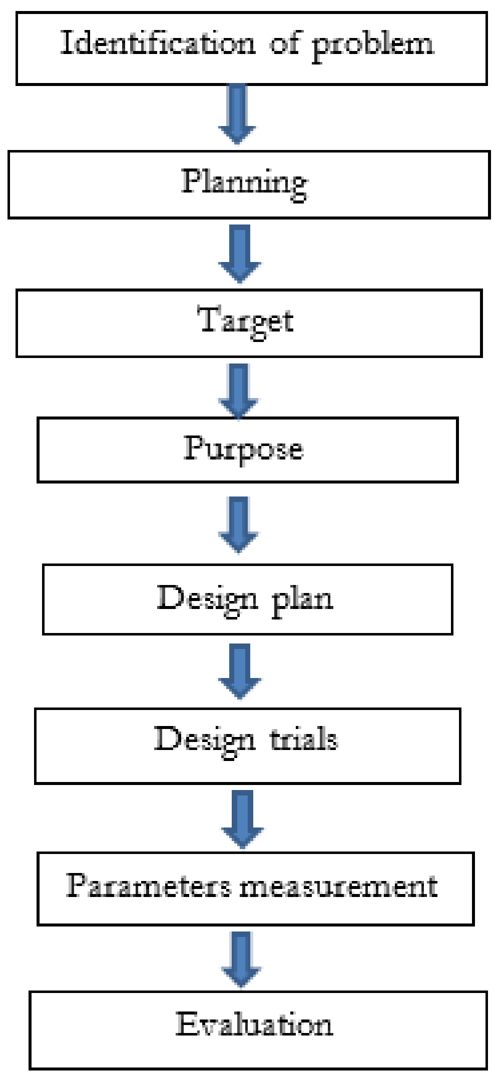


*Figure 1.*
The Research Framework

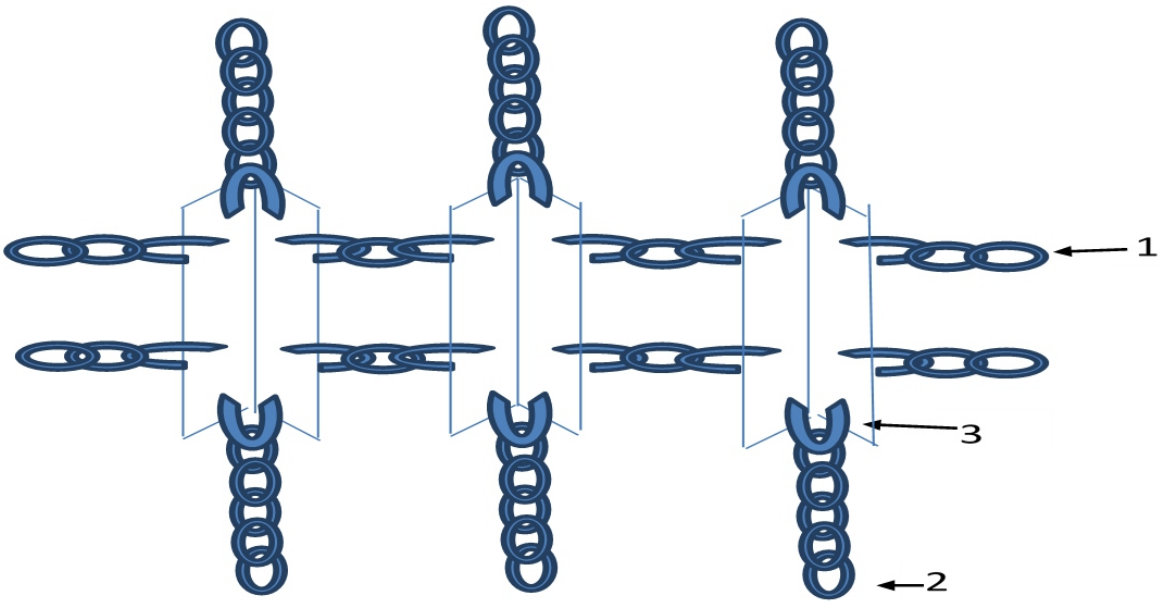


*Figure 2.*
Iron Elbow Tool And Straight Chain (front View)

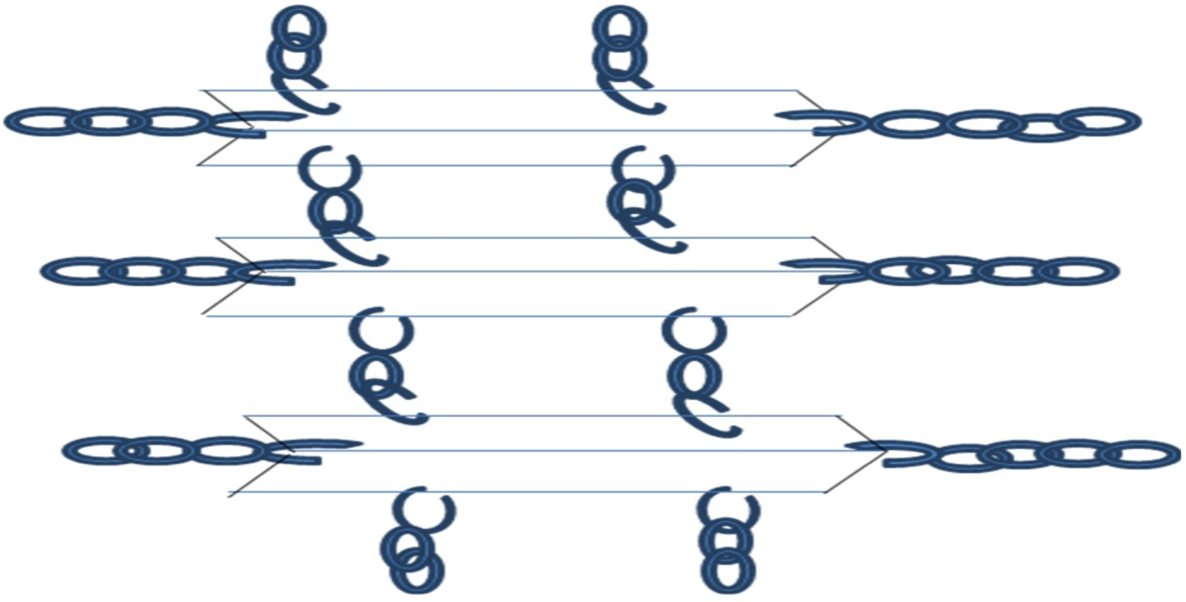

*Figure 3.*
Iron Elbow Tool and Straight Chain (Top View)

*Data Analysis*

The field data in this research is truck wheel slippage, productivity, traction coefficient, and soil damage and processed into tabulated form. The analysis tools used are average. The cost of transport production is calculated using the formula from Nugroho (2022) below:

Fixed costs: costs that run continuously according to the length of use of the tool.

a. Depreciation fee (IDR/Hour)

$$D = \frac{M - R - Tool\ Proce}{N \times Time\ per\ year} \quad (1)$$

b. Capital interest cost (IDR/Hour)

$$B = \left\{ \frac{\left( \frac{(M-R)(N+1)}{2N} + R \times 0{,}0p \right)}{t} \right\} \quad (2)$$

Information:
D = Depreciation cost (IDR/hour)
B = Interest on capital (IDR/hour)
M = Purchase price of equipment (IDR)
R = residual value of tools (IDR)
N = tool life (years)
0.0p = Bank interest (%)
T = Number of hours worked/year.

c. Tax (IDR/Hour)

$$Tax = \frac{Tool\ price \times 0{,}6 \times 0{,}02}{1000/Hour} \quad (3)$$

d. Insurance (IDR/Hour)

$$insurance = \frac{Tool\ price \times 0{,}6 \times 0{,}03}{1000/hour} \quad (4)$$

2. Operational/variable costs: costs when the tool is used.
   a. Repair and maintenance cost (a)

$$a = \frac{spare\ part\ per\ year\ (Idr)}{working\ hours\ a\ year\ (hour)} \quad (5)$$

   b. Fuel cost (b)

$$b = \frac{fuel\ (liter)}{working\ hour\ a\ year\ (jam)} \times price \quad (6)$$

   c. Oil and lubricant cost (c)

$$c = \frac{lubricant\ (liter)}{working\ hours\ a\ year\ (hour)} \times price \quad (7)$$

   d. Supplementary cost (d

$$d = \frac{price\ (IDR/hour)}{Use\ Age\ (hour/year)} \quad (8)$$

   e. New tool making/ NTM (e)

$$e = NTM\ (IDR/hour) \quad (9)$$

3. Operator wage cost (OWC)

$$OWC = operator/helper\ wage\ (IDR/hour) \quad (10)$$

4. Tranporting cost (TC)

$$TC = \frac{1+2+3+4+5+6+7+8+9+10}{P} \quad (11)$$

To determine the effect of using logging tool on slippery roads and three different grades of slope, productivity, production costs and soil damage, the t-test with SPSS 25 was analyzed.

The hypothesis of this research is:
- Ho: Using assistive devices can not significantly affect slippage, productivity, production costs of transporting wood, and soil damage.
- Ha: The use of assistive devices can significantly affect slippage, productivity, production costs of transporting wood, and damage to the soil.
- If the probability value < 0.05, Ho is accepted and Ha is rejected. Meanwhile, if the probability value is > 0.05, Ho is rejected and Ha is accepted.

## Results and Discussion

*Slip at Wood Transport*

Skidding is a major challenge affecting the stability of autonomous vehicles during speed and is difficult to control in real-time (Harbor et al., 2021). Slip conditions are a major road safety problem. In South Korea, 8,849 traffic accidents caused by slips happened in the last three years (Jang, 2020). According to Idkham et al. (2018), an increase in tensile load affects wheel slippage. This continuous situation will result in soil deformation, increasing wheel rotations while the wheel mileage will be shorter. Using wheel holsters for transportation equipment from straight iron chains resulted in average slippage on slope classes of 0-8%, 9-15%, and 16-25%, respectively, which were 1.74%; 3.35%; and 4.23. % (presented in Table 1).

The high slippage on the slope class 16-25% indicates that the truck's ability to transport wood on the slope class faces obstacles that slip. The slippery road conditions cause one of the truck wheels to lose traction. Table 1 also shows that the use of assistive devices resulted in a lower average slippage than not using assistive devices with a difference of 7.2-10.94%.

The strength of the engine and other mechanical parts of the vehicle generally determines the vehicle's ability in sloping road conditions. Rees (2021); Sunggono & Wasiwitono (2017) state that trucks generally have a relatively large weight and affect the engine's strength, so the speed reduction when climbing is decisive in affecting the traffic flow. Trucks generally have a relatively large weight and affect the engine's strength, so the speed reduction when climbing is decisive in affecting the traffic flow. The light vehicle allows the excess thrust to remain greater so that the climbing ability and acceleration of the car increase. Roads are generally designed to have a maximum road gradient of less than 7%. However, for special cases such as mountainous areas at the Turracher Höhe location in Austria the gradient of the sloping road can be found up to 26%. The research results of Kurnia et al. (2018), show that haul road conditions greatly affect tire performance because the tires are in direct contact with the road surface. The road segment with a slope of 5% makes it difficult for the dump truck to move and the tire performance to move harder. The steep slope causes a heavier workload on the truck tires and causes slippage.

Table 1.
*Slip Average Using and Without Iron Elbow and Straight-chain Tool*

| Slope (%) | Slip | | Difference (%) |
|---|---|---|---|
| | use | Not use | |
| 0-8 | 1.74 | 8.94 | 7.2 |
| 9-15 | 3.35 | 12.34 | 8.99 |
| 15-25 | 4.23 | 15.17 | 10.94 |

Table 1 also shows that the use of assistive devices resulted in a lower average slippage than not using assistive devices with a difference of 7.2-10.94%. Using a tool can reduce the rate of slippage, this is because the shape of the chain link that is connected to a straight-angled iron can form a pattern that wraps the grooves of the truck tires so that the tools grip the truck tires.

The shape of this iron elbow and straight iron chain resembles a battle-steel tank. If the truck does not use an assistive device, the truck's wheels will experience an imbalance in the power distribution from the engine in the event of a slip so that the wheel will spin with a fast motion without moving forward.

The high slippage in this study is not only influenced by the slope of the soil texture but also plays a role in the high slippage. Wahyudi & Khaerudini (2020) research shows that slippage occurs because the soil undergoes deformation or changes in shape due to the internal tensile force between the cohesion soil particles is not strong enough to withstand shear loads due to the movement of the truck wheels. The surface of wet clay and clay soils tends to be slippery and causes the wheels to slip, this occurs because the soil cohesion value decreases due to the influence of water and soil type. The tools needed to increase wheel traction on wet soil, especially clay, are carried out by increasing the area of the wheel's tangent to the ground.

The results of the research by Kurniawan et al. (2019), show that the geometry of the production haul road on the northern route connects the front loading to the northern disposal area as far as 600 meters, consisting of 6 segments. The haul road still has many potholes and uneven road surface conditions due to the expansive soil material containing clay, which expands when it rains and shrinks when it is hot so that the road surface becomes uneven. The road is also relatively flat or without a standard cross slope. After the rain, it will cause puddles of water which can reduce the quality of the road material and risk causing the vehicle to skid and the formation of undulation on the road.

The results study of Rahman et al. (2018), shows variations in traction distribution with 45% to the front wheels and 55% to the rear wheels, almost all the adhesion limits can be passed by the vehicle. However, when the vehicle passes through a wet mud road with a gradient of 15%, then a stationary vehicle does not move because the traction generated is less than the resistance when going uphill to pass it.

The use of assistive devices in this study in the form of wheel holsters for transportation of straight iron chains resulted in a lower average slippage than the results of research on the use of assistive devices in the form of wheel holsters for transportation of crossed iron chains as shown in Yuniawati et al. (2015) in the research area of RPH Ciogong, BKPH Tanggeung, KPH Cianjur with a slope of 0-8%, 9-15% and 16-25%, respectively, at 3.24%; 6.11%; and 7.58%. The results of the t-test analysis to determine the effect of using assistive devices on the occurrence of slippage is the probability value (0.301) > 0.05, then Ho is rejected and Ha is accepted, meaning that the use of assistive devices significantly affects the occurrence of slippage.

The slip rate of each wheel can be controlled close to the optimal slip level with strong convergence and anti-interference ability under different working conditions. It can take full advantage of the road adhesion ability and the coupling ability between the motors to improve the dynamic performance and smoothness of the vehicle (Gao & Lin, 2021) .Using a tool on the truck wheel can reduce the occurrence of slippage.

*Productivity and Cost of Wood Transport*

The size of the productivity is determined by many factors, including the performance of the conveyance and loading equipment, the operator's ability, the condition of the road that is passed by the width of the road on straight roads and bends, road slope (grade) or incline, cross slope and superelevation). Better road conditions can affect the total time of transportation because of the increase in the quality of roads, so the speed of transportation equipment will increase. The higher the conveyance speed, the shorter the cycle time of the conveyance, so that it will affect the productivity value of the conveyance used and the width of the road on straight roads and bend roads, road grade and superelevation affect the travel time of loading and return travel time empty (Firmansyah et al., 2018; Mustofa et al., 2019).

According to Zulkarnain (2020), If a vehicle goes through an uphill road, the required traction power will also increase, approximately proportional to the road's incline to be traversed. Likewise, when the road goes down, the force required decreases by the same value as the road uphill. Road ramps are expressed in percent (%), which is the ratio between changes in height per unit length of the road. The addition and reduction of traction force due to an incline or descent can be directly proportional to the % rise and fall of the ramp.

The average productivity and cost of transporting wood using tools and not using tools are presented in Table 2. Table 2 shows that the average productivity of transporting wood using or without tools on slopes is 16-25% lower than on another slope. The result shows that the flatter slope of the transport road, the lower the average productivity of transportation. The more uphill the transport road, the higher the slippage.

The condition of the road is uphill, so the rotational speed of the truck's wheels cannot be followed by the overall speed of the vehicle. As a result, the speed difference between the wheels and the vehicle is getting bigger.

Table 2 shows that assistive tools on that variation slope have higher average productivity of transporting wood than those not using tools, respectively 33.89; 54.47%; and 58.19%. The difference can be categorized as high because of the difference of more than 50% (especially on slopes > 8%). The low average productivity of wood transportation is due to the higher average slippage that occurs when not using tools. The high slippage causes the braking activity always to occur and the condition of the wheels cannot rotate perfectly causing the truck to lose time. The wasted time is higher. High slippage can hinder the smooth transportation of wood.

Table 2.
*Average of Wood Transport Porductivity and Cost*

| Slope (%) | Productivity ($m^3$.km/hour | | Production Cost (IDR/$m^3$.km) | | Productivity difference (%) | Production cost difference (%) |
|---|---|---|---|---|---|---|
| | use | Not use | use | Not use | | |
| 0-8 | 128.05 | 84.66 | 1,906.96 | 3,105.58 | 33.89 | 38.60 |
| 9-15 | 114.59 | 52.17 | 2,130.95 | 3,835.16 | 54.47 | 44.44 |
| 16-25 | 103.51 | 43.28 | 2,359.02 | 5,172.33 | 58.19 | 54.39 |

The high average productivity of wood transportation has consequences for the low average production costs as shown in Table 2. The average production cost of transporting wood using tools can reduce the production costs of transporting wood than not using tools (on a slope of 0-8%, 9-15%, and 16-25%) with a difference of 38.60%-54.39%. The study from Lestari et al. (2019), shows that with a brand B rolling chassis, WCV vehicles can climb up to 30° with the highest speed of 8.2 km/hour in low-mode operation. According to Arrofah et al. (2017) an increase in effective working time by reducing or avoiding the time of obstacles that can be avoided by the operator.

Based on the t-test analysis results, the effect of the use of assistive tools on the productivity of wood transportation and production costs has a probability value of (0.266) > 0.05, or Ho is rejected and Ha is accepted, it means that the use of assistive tools significantly increases the productivity of wood transportation. Meanwhile, the effect of tools on the production cost has a probability value of (0.108) > 0.05 or Ho is rejected and Ha is accepted, meaning that the use of tools affects the production cost of transporting wood significantly.

*Soil Damage Caused by Slip*

The increasing use of off-road vehicles such as transport trucks causes damage. Excessive use of these vehicles leaves marks on the soil, such as deepening grooves or ruts that negatively affect vegetation, water absorption and runoff characteristics, and aesthetics (Hambleton & Drescher, 2008).

The presence of slips on truck tires causes soil damage that is getting worse. For this reason, tools are needed to reduce the severity of the damage to the soil. The soil damage in this study was holed forming ditches with varying depths. The results of measuring the average depth of soil formed using tools and not on slopes of 0-8%, 9-15%, and 16-25% are presented in Table 3.

Table 3.
*Average of Soil Depth Formed by Slippage*

| Slope (%) | Soil depth (cm) | | Difference (%) |
|---|---|---|---|
| | Use | Not use | |
| 0-8 | 1.10 | 5.57 | 80.25 |
| 9-15 | 1.94 | 10.79 | 82.02 |
| 15-25 | 2.41 | 14.34 | 83.19 |

Table 3 shows that the average soil depth that occurs without using tools on three slopes is deeper than using tools with a difference of 80.25-83.19%. The result indicates that slippage due to not using tools on three slopes can result in higher soil damage. A skidded truck tire tends to erode the topsoil until a ditch is formed. The driver tries to find maximum traction so the truck tires can rub against the ground. Maximum traction is required to avoid slippage.

Soil damage due to slippage can cause damaging the soil structure. According to Suprayogo et al. (2001), to soil structure begins with a decrease in the stability of soil aggregates, this causes soil aggregates to be relatively easily crushed into a fine shape to form soil crusting which is solid and hard when dry.

Research results from Ibrahim & Abdullah (2013), show that weak soil aggregates will be released, dissolve into groundwater, and clog the pore spaces. Soil clogged with pore spaces cannot pass water, so most of the rainwater that falls to the soil surface will become surface runoff, eroding and transporting the soil surface layer to be deposited in other areas (Sukisno et al., 2011).

According to Yuniawati & Suhartana (2015) research, soil damage due to slippage can result in soil erosion and increase surface runoff.

Soil erosion is very dangerous because it can damage the timber transport road, a means of transportation to remove wood from the forest. The smooth distribution of wood is hampered. The results of the t-test analysis to determine the effect of using tools on soil damage is the probability value (0.113) > 0.05, meaning that Ho is rejected and Ha is accepted, meaning that the use of tools affects soil damage significantly.

## Conclusion

The use of iron elbow and straight-chain tools in transporting wood on slopes of 0-8%, 9-15%, and 16-25% can result in lower slippage than not using tools, with a difference of 7.2%, 8.99%, and 10.94%. The slope and soil texture also affect the occurrence of slippage. The average productivity of transporting wood without using tools is lower than using tools on slopes 0-8%, 9-15%, and 16-25% with a difference of 33.89%, 54.47%, and 58.19%.

The higher the average productivity of transportation, the lower the transport production cost. Using iron elbow and straight-chain tools can reduce production costs higher than not using tools on slopes of 0-8%, 9-15%, and 16-25%, with a difference of 38.60%, 44.44%, and 54.39%. The soil depth formed by slip without using tools on slopes of 0-8%, 9-15%, and 16-25%, is 5.57 cm, 10.79 cm, and 14.34 cm. The tool still has weaknesses, such as installing the chain takes a few minutes. In the future, the tool can add a hook lock that makes it easier to tie the chains to the tires.

## References


Allman, M., Dudáková, Z., Jankovský, M., & Merganič, J. (2021). Operational parameters of logging trucks working in mountainous terrains of the western carpathians. *Forests,* 12(6), 1–13. doi: 10.3390/f12060718

Arina. (2020, December 14). Ternyata Ini Penyebab Selip Pada Truk.

Arrofah, M., Pitulima, J., & Mardiah. (2017). Productivity Evaluation of Dug-Loading Equipment and Transport Equipment for Overburden Stripping in August 2016 at Pit 3 East Banko Barat Mining PT Bukit Asam (Persero) Tbk. *Jurnal Mineral,* 2(2), 1–8.

Battiato, A., Alaoui, A., & Diserens, E. (2015). Impact of Normal and Shear Stresses Due to Wheel Slip on Hydrological Properties of an Agricultural Clay Loam: Experimental and New Computerized Approach. *Journal of Agricultural Science,* 7(4), 1–19. doi: 10.7892/boris.66320.

British Columbia Forest Safety Council. (2015). *Logging Trucks in British Columbia.* BC Forest Safety Council on Behalf of the Trucking Advisory Group.

Bulgakov, V., Aboltins, A., Beloev, H., Nadykto, V., Kyurchev, V., Adamchuk, V., & Kaminskiy, V. (2021). Maximum Admissible Slip of Tractor Wheels without Disturbing the Soil Structure. *Applied Sciences,* 11(15), 6893. doi: 10.3390/app11156893

Faizal, A. (2014). Slip Control Design on Haul Truck Using Sliding Mode Controller Method. *Jurnal ECOTIPE,* 1(2), 1–7. doi: 10.33019/ecotipe.v1i2.46

Firmansyah, Ibrahim, E., & Suwardi, F. R. (2018). Technical Stucy of Geometry Production Road to Improved Overbuden Production at The Articuled Dump Truck Volvo A 40F in PT Lematang Coal Lestari District Muara Enim. *Jurnal Pertambangan,* 2(3), 19–26. doi: 10.36706/jp.v2i3.7396

Gao, X., & Lin, C. (2021). *Electromechanical Coupling Approach for Traction Control System of Distributed Drive Electric Vehicles.* E3S Web of Conferences, 236. doi:10.1051/e3sconf/202123601007

Hambleton, J., & Drescher, A. (2008). *Soil Damage Models for Off-Road Vehicles.* In K. R. Reddy, M. V Khire, & A. N. Alshawabkeh (Eds.), Geosustainability and Geohazard Mitigation Procedings of Sessions of Geocngress . ASCE.

Harbor, M. C., Eneh, I. I., & Ebere U C. (2021). Precision Control of Autonomous Vehicle under Slip Using Artificial Neural Network. *International Journal of Research and Innovation in Applied Science,* 6(9), 51–55. www.rsisinternational.org

Hoever, C., & Kropp, W. (2015). A Model for Investigating the Influence of Road Surface Texture and Tyre Tread Pattern on Rolling Resistance. *Journal of Sound and Vibration,* 351, 161–176.

Ibrahim, A. A., & Abdullah, M. A. (2013). The Effects of Vehicle Speed and Type of Road Surface on the Longitudinal Slip of Tires and the Brake Stopping Distance. *Engineering and Technology Journal,* 31(10), 1854–1869.

Idkham, M., Mandang, T., Hermawan, W., & Pramuhadi, G. (2018). Model Performance Analysis of Narrow Lug Wheel for Wetland at Soil bin. *Jurnal Keteknikan Pertanian,* 6(1), 1–10. doi: 10.19028/jtep.06.1.15-22.

Jang, J. (2020). Wheel Slip-based Road Surface Slipperiness Detection. *The Open Transportation Journal,* 14(1), 186–193. doi:10.2174/1874447802014010186

Jansson, V. (2022). *A Literature Study of Rolling Resistance and Its Affecting Factors [Thesis]*. KTH Royal INstitute of Technology.

Koirala, A., Kizha, A. R., & Roth, B. E. (2017). Perceiving Major Problems in Forest Products Transportation by Trucks and Trailers: A Cross-sectional Survey. *European Journal of Forest Engginering,* 3(1), 23–34.

Kumar, A., & Gupta, A. (2021). Review of Factors Controlling Skid Resistance at Tire-Pavement Interface. In Advances in Civil Engineering (Vol. 2021, pp. 1–16). *Hindawi Limited*. doi: 10.1155/2021/2733054

Kurnia, M. J. D., Guntoro, D., & Zaenal. (2018). *Performance Evaluation of Dump Truck Tires in Andesite Mining Activities (Case Study of PT Desira Guna Utama, Argapura Village, Cigudeg District, Bogor Regency, West Java Province)*. Prosiding Teknik Pertambangan, 124–131.

Kurniawan, A., Amin, M., & Bochori. (2019). The Effect of Road Geometry Before and After the Improvement of Roads on The Productivity and Fuel Consumption and Fuel Ratio. *Jurnal Pertambangan,* 3(1), 26–35.

Lestari, P. D. R., Sartomo, A., & Yuwono, T. (2019). Road Load and Wheel Traction Simulation of 4WD Rolling Chassis Selection for Water Cannonr Vehicle. *Majalah Ilmiah Pengkajian Industri,* 13(1), 65–74. doi: 10.29122/mipi.v13i1.3299

Mirosław, T., & Mirosław, M. (2021). *Problem of Slip Definition in Driving Systems.* MATEC Web of Conferences, 338, 1–10. doi: 10.1051/matecconf/202133801019.

Mustofa, A., Wicaksono, J. G., Nurhakim, N., Afriko, A., & Melati, S. (2019). Mine Transport Road Improvement: Effect of Changes in Road Layer Structure on Transport Equipment Productivity. *Jurnal Himasapta,* 1(01), 1–10. doi: 10.20527/jhs.v1i01.906

Nugroho, B. (2022). *Analisis Biaya Pemanenan*. Institut Pertanian Bogor.

Radite, P. A. S., Hermawan, W., & Soembagijo, A. (2008, November). *Design and Testing of Dry Land Steel Wheels for 2-Wheel Tractors.* Prosiding Seminar Nasional Teknik Pertanian .

Rahman, R. F., Wikarta, A., & Sutantra, I. N. (2018). Design and Analysis of Traction Characteristics on Multipurpose Rural Cars WAPRODES. *Jurnal Teknik ITS,* 7(1), 21–26. doi: 10.12962/j23373539.v7i1.29825

Rees, S. (2021). Review of Vertical Allinement on Roads Case Study: Mareku-Afa-Afa Road. *Jurnal Akrab Juara,* 6(5), 84–96.

Salehi, M., Noordermeer, J. W. M., Reuvekamp, L. A. E. M., Tolpekina, T., & Blume, A. (2020). A New Horizon for Evaluating Tire Grip Within a Laboratory Environment. *Tribology Letters,* 68(37), 1–18. doi: 10.1007/s11249-020-1273-5

Sukisno, Hindarto, K. S., Hasanudin, & Wicaksono, A. H. (2011). *Mapping Potential and Status of Soil Damage to Support Biomass Productivity in Lebong Regency.* Prosiding Seminar Nasional Budidaya Pertanian, 140–156.

Sunggono, W. S. W., & Wasiwitono, U. (2017). Perancangan dan Analisa Karakteristik Traksi Sistem Powertrain Mobil Produksi Pedesaan. *Jurnal Teknik ITS,* 6(1), 170–173. doi: 10.12962/j23373539.v6i1.22321

Suprayogo, D., Widianto, Purnomosidi, P., Widodo, R. H., Rusiana, F., Aini, Z. Z., Khasanah, N., & Kusuma, Z. (2001). Degradation of Soil Physical Properties as a Result of Forest Land Use Conversion to Monoculture Coffee Systems: A Study of Changes in Soil Macroporosity. *Jurnal Agrivita,* 26, 60–68.

Wahyudi, D. T., & Khaerudini, D. S. (2020). Anti-Slip Shoe Design for Colt Diesel Wheels on Muddy Roads. *Jurnal Teknik Mesin,* 13(1), 6–12. doi: 10.30630/jtm.13.1.278

Yuniawati, & Suhartana, S. (2015). The Effect of Slippage on Soil Damage in the Transportation of Pine Merkusi. *Jurnal Sains &Teknologi Lingkungan,* 7(2), 95–107. doi: 10.20885/jstl.vol7.iss2.art4

Yuniawati, Y. (2015). *Skid Reduction on Acacia Mangium Wood Transport Dirt Road*. MECHANICAL, 6(1), 36–42. doi: 10.23960/mech.v6.i1.201505

Yuniawati, Y., Dulsalam, D., Mansyur Idris, M., Suhartana, S., & Sukadaryati, S. (2015). Auxiliary Tools of Log Hauling Truck to Reduce Slipped Wheel on Soil Road Without Paving. *Jurnal Penelitian Hasil Hutan*, 33(4), 387–395. doi: 10.20886/jphh.2015.33.4.387-395

Zulkarnain, F. (2020). *Pemindahan Tanah Mekanis Dan Peralatan Kontruksi* (M. Arifin, Ed.; Pertama). UMSU Press.