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Development and evaluation of wireless turning indicator for agricultural tractor-trailer system to ensure road safety

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Abstract
Most of the age-old tractor-trailers were not fitted with proper indicators such as stoplight or tail light. As a result, the vehicle behind the trailer cannot know the direction of the tractor-trailer during turning, and it leads to accidents in road march. For example, when the trailer turns right, the driver must first swing to the left to get enough clearance to execute a right turn safely. The trailer can hit a vehicle in the adjacent lane when it is not done properly, sometimes crushing the vehicle between the trailers. To overcome these types of difficulties, the development of wireless turning indicators for agricultural tractor-trailer systems to ensure safety was considered. The system consists of a safe wireless radio frequency module, transmitter circuit, receiver circuit, and lighting system. The braking system was provided with a stoplight at the rear of the trailer, which emits red light intended to warn of the vehicles slowing down or stopping. The system was evaluated and concluded that cent percent of the drivers can visualize and drive safely after installing tail lights in the trailers.

Keywords: Indicator, RF Module, safety, tractor-trailer, brake

Introduction
The utilization of tractor-trailers for various purposes increases by one side, on the other side, road accidents are also escalating. The current assessment shows that road accidents are not obeying the traffic rules, inappropriate usage of indicators while turning right or left while driving the vehicles, and so on (Usha *et al.*, 2020) [15]. Tractor-trailers were recorded the highest percentage of accidents, i.e., 27.7% among all types of accidents taking place in agriculture (Nag and Nag, 2004) [10]. A vision of the road wherein every driver actuates the turn signal on time and accurately is both promising and safe (Ponziani R, 2012). In the farm machinery category, the highest number of accidents was associated with tractor and tractor operated implements (31%) (Gite *et al.*, 2010) [5]. The tractor-trailer accidents reported improper indication, goods overload, weight limit, and lack of driver training and experience. Cobb (1990) [2] carried out a roadside survey of vehicle lighting in the UK, including rear signal lighting, and found that dirt typically reduced the luminous intensity of vehicle lighting by 30–50 percent. Driving is a visual task since driving involves more than seeing. Most visual tasks are three components: visual, cognitive, and motor. The visual components are the process of extracting information relevant to the performance of the task using the sense of sight. The cognitive components are how sensory stimuli are interpreted, and appropriate action determined. The motor components are the process by which the stimuli are manipulated to extract information, and the action decided upon are carried out. All three components are involved in driving, but lighting affects only the visual components. The role of lighting in driving enables the transfer of information from the environment to the human visual system. Lighting achieves this role by making objects visible. Three measures determine the stimulus: visual size, luminance contrast, and color difference. Lighting has a role in improving traffic safety through greater visibility (Peter R. Boyce, 2009). In addition, it is reported that weather conditions such as fog and heavy illumination conditions such as day-time and night-time and observation conditions such as viewing angle affect several visibility indices. These include subjective evaluation, response time, and distance estimation. (Cavallo *et al*., 2001, Hautiere *et al*., 2009, Mori *et al*., 2006, Khumalo, 2014, Plainis *et al*., 2006, Sivak *et al*., 2000, Tobitani *et al*., 2013) [1, 8, 7, 11, 13, 14]. The subjective judgments resulted that changes in intensity (measured in Candela) strongly reduced response time, while changes in the light area had little effect (Flannagan, 1998) [3].

As per the Automotive Research Association of India (ARAI), the agricultural trailers are classified as fixed and tipping platform trailers. On the other hand, agricultural trailer fitted with pneumatic tires and operated by agricultural tractors (IS: 8213-2000) are categorized with balanced (double or multiple axles) and semi-balanced trailers (single axle).

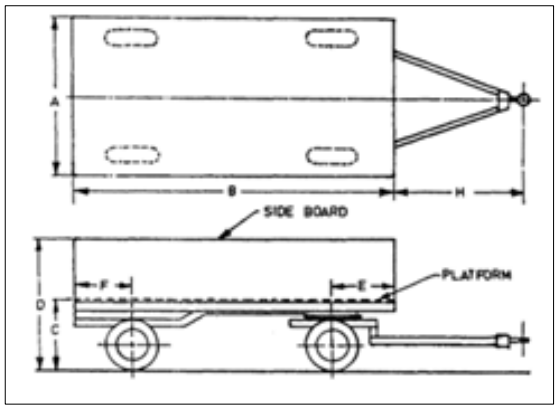

Fig 1: Balanced trailers up to 10 tonnes capacity

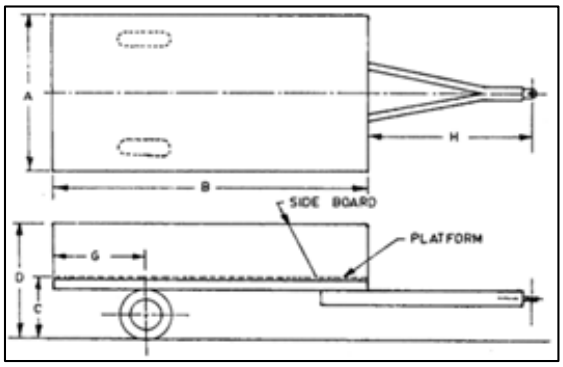

Fig 2: Semi-trailers up to 6 tonnes capacity

Nearly 4.3 million tractors were in operation in India, and every twenty rural households owned a tractor in 2011. Presently about 5 lakh tractors are sold annually (Anon.). All the dimensions of existing trailers were measured and verified according to Indian Standard IS 8213 (2000). The dimensions, safety system of existing tractor-trailers (Figure.3), and other safety features are detailed in Table.1.

Table 1: Tractor-trailer dimensions

S. No	Parameters	As per IS: 8213-2000	Balanced trailers, m	Semi-trailers, m
1	Overall width of the trailer	Not exceed 2.5 m	1.20	2.13
2	Overall length of the platform	5 m for up to 6 t capacity & 6.7 m for above 6 t capacity	4.90	4.22
3	Height of the trailer to the top of the platform	Not more than 1.5 m	0.58	0.73
4	Height of the trailer to the top of the sideboard	Not more than 2.2 m	2.00	2.00
5	Edge of the platform to the centre of front wheel	0.80 m	0.70	0.80
6	Tipping angle of the body, in case of tipping type	42° to 50°	Fixed type	42 °

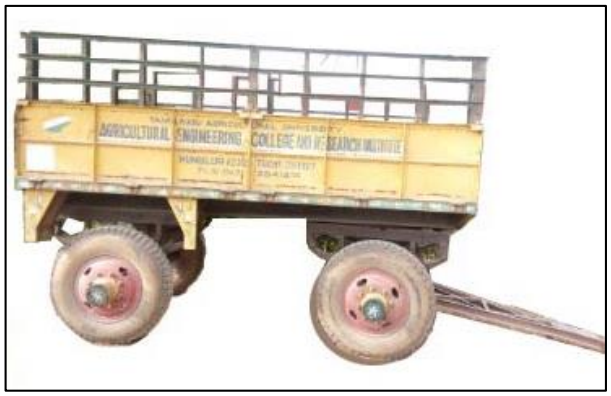

Fig 3: Four wheel tractor trailer

Agricultural trailers are categorized based on the axle as follows

- Category R1: Single axle trailer who's Gross Vehicle Weight does not exceed 3.0 tons.
- Category R2: Single axle trailer who's Gross Vehicle Weight exceeds 3.0 tons and does not exceed 6 tons.
- Category R3: Any double axel trailer who's Gross Vehicle Weight does not exceed 10 tons.
- Category R4: Any double axel or multi-axle trailer who's Gross Vehicle Weight exceeds 10 tons.

At present, existing tractor-trailer systems are not supported by proper lighting provisions. Even the operators of the tractors may not know the weight limit of the tractor-trailer and safety rules. Signal lightings are lighting incorporated to indicate the presence of or give information about a vehicle's movement. Signal lighting includes front position lamps, rear position lamps, side marker lamps, license plate lamps, turn lights, hazard flashers, stop lamps, rear fog lamps, reversing lamps, and daytime running lamps, as well as retroreflectors. The visibility of a signal lamp depends on its luminance, size, shape, and color, the background against which it is seen, and the state of adaptation of the driver.

Materials and Method

The agricultural trailers are classified as balanced trailers and semi-trailer. Both types of trailers may be fitted with the fixed or tipping platform. The capacity of the single-axle trailers shall be not more than five tonnes. The stoplight was used as a brake-operated lighting device that emits red or amber light at the rear of the vehicle intended to warn of the slowing down or stopping the vehicle. The direction indicator was fixed as a lighting device to show in which direction the driver intends to turn by giving a flashing light on the side of the vehicle towards which the turn will be made. Moreover, when the vehicle is reversing or is about to reverse, reversing light is used to provide a warning signal to pedestrians and other drivers.

The standard IS 8213 (2000): Agricultural Tractor Trailer FAD 11: Agricultural Tractors and Power Tillers specifies material, constructional and other requirements of agricultural trailers fitted with pneumatic tires and operated by an agricultural tractor. It covers the requirements of balanced trailers up to 10 tonnes and semi-trailers up to 5 tonnes capacity. The circuit diagram of wireless turning indicators is shown in Figure.4. The RF module consists of 433 MHz RF Transmitter and Receiver, HT12E Encoder IC, HT12D

Decoder IC, Push Buttons, LEDs, Resistor, 7805 Voltage Regulator, 9V Battery, Bread Board, Connecting wires. The developed wireless turning indicators system consists of receiver, transmitter, LED light is shown in Figure.5.The wireless turning indicators system can be activated through a manual and steering control system.

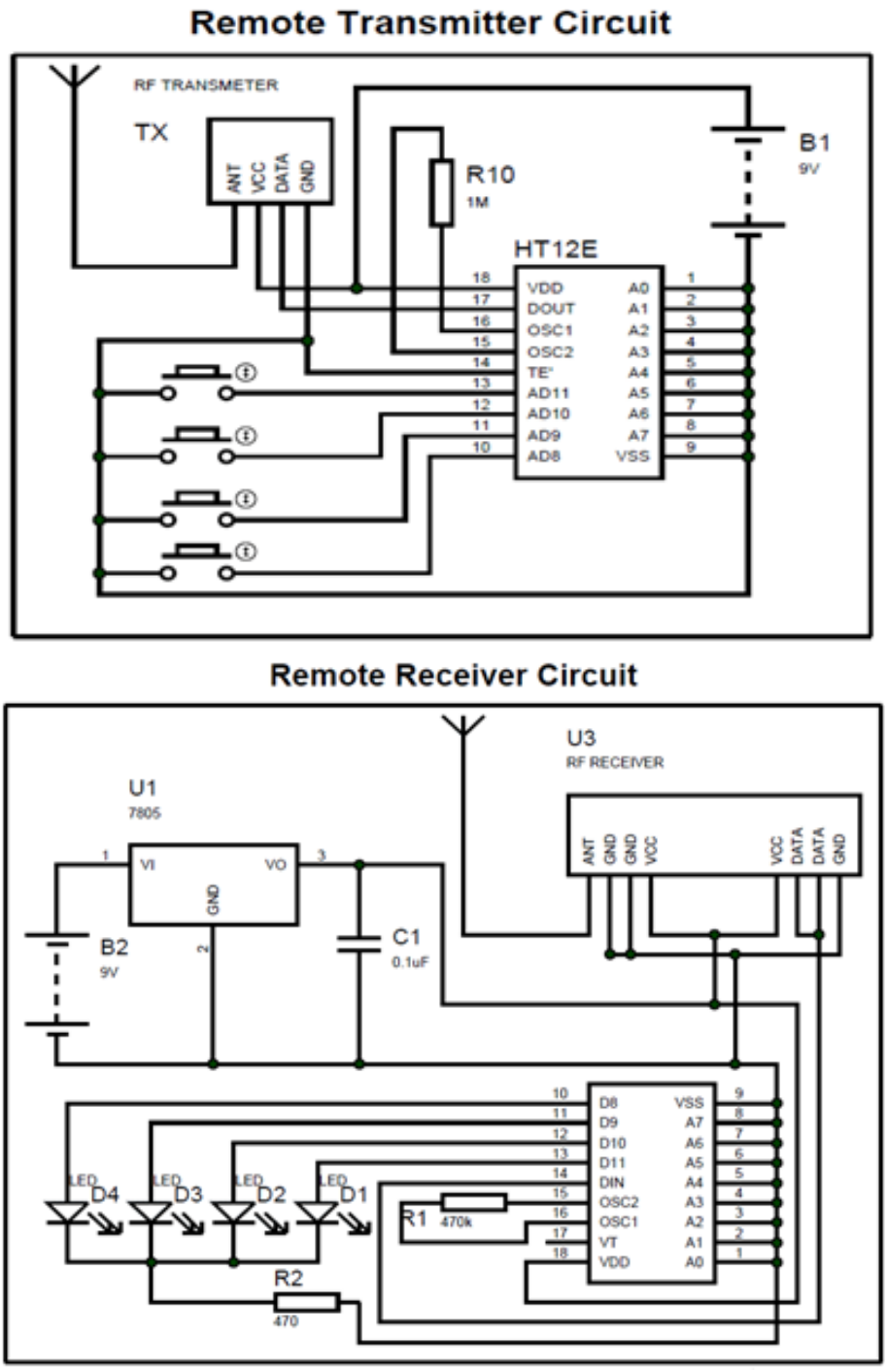

Fig 4: Circuit diagram of wireless turning indicators

The radiofrequency module is preferred, it can produce a signal and pass through the obstacles. The corresponding frequency range varies between 30 kHz and 300 GHz. This RF module comprises an RF Transmitter and RF Receiver. The transmitter/receiver pair operates at a frequency of 434 MHz. An RF transmitter receives serial data and transmits it wirelessly through RF through its antenna connected at a pin 4. The transmission occurs at the rate of 1 Kbps – 10 Kbps. The transmitted data is received by an RF receiver operating at the same frequency as the transmitter. The RF module is often used with a pair of encoders/decoders. The encoder is used for encoding parallel data for transmission feed, while a decoder decodes reception. HT12E-HT12D, HT640-HT648, etc., are some commonly used encoder/decoder pair ICs. The laboratory prototype safety wireless radio frequency (RF) module was developed as shown below (Figure.6. a & 6.b).

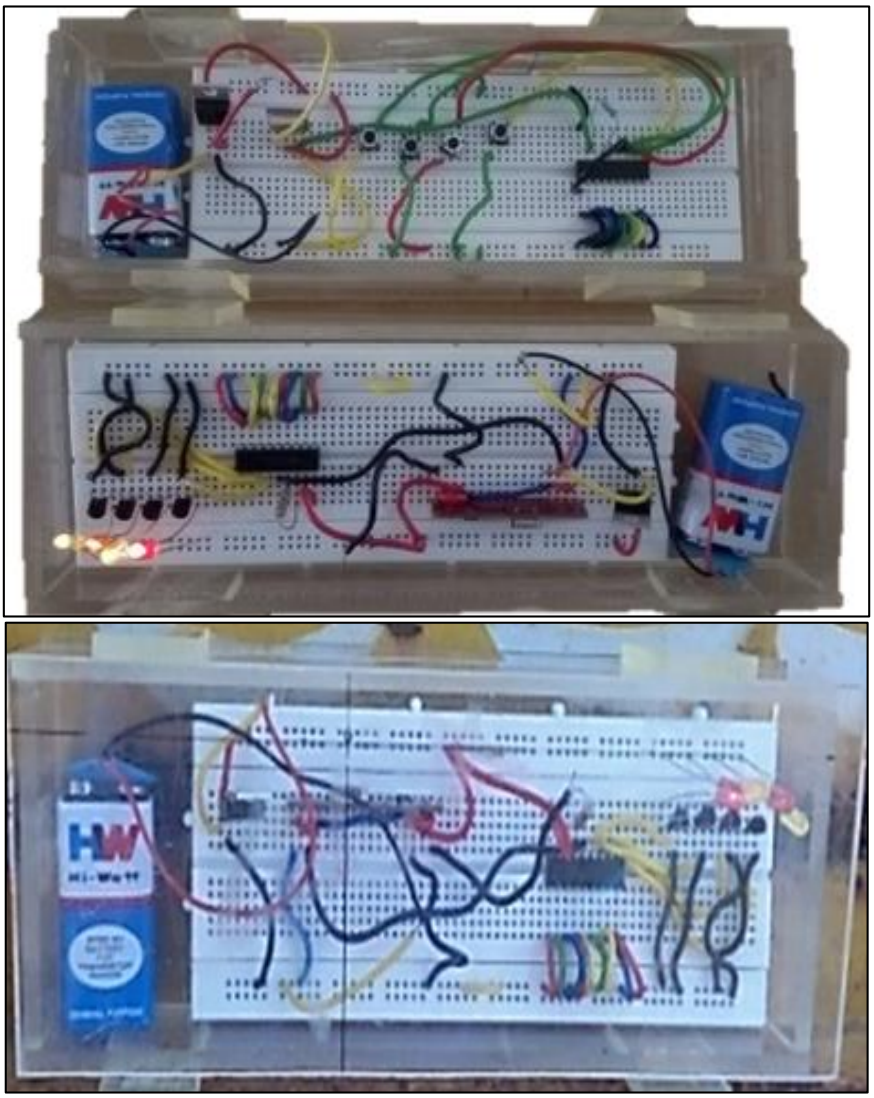

Fig 5: Wireless turning indicators

The improved prototype model of wireless turning indicator (as per standard IS: 8213-2000) is shown in Figure.7 (a & b). It consists of a transmitter with display and power source, receiver with indicators, and parking brake sensor. In addition, the two amber flashing reversing lamps (warning lamps) conforming to IS 4060 or IS 13135 as symmetrically mounted and as widely spaced laterally as practicable, visible from both front and rear, mounted at the height of 1000 mm, and it should flash together at a rate of 60 to 120 flashes per minute.

Fig 6.b: Receiver with indicators

Fig 6.a: Transmitter unit

Fig 7.a: RF wireless setup

Fig 7.b: Working condition with RF setup

Table 2: Lights and signalling devices position and arrangement

S. No.	Lighting and Light-signalling Devices	Number/ Orientation / Colour
1	Rear Position Lamp (Tail lamp)	2/ Rear/ Red
	Position / Arrangement i. The point on the illuminating surface farthest from the median longitudinal plane of the trailer shall be not more than 500 mm from the extreme outer edge of the vehicle. ii. The distance between the inner edge of the two illuminating surfaces shall be not less than 500 mm. This distance may be reduced to 400 mm, where the overall width of the trailer is less than1300 mm. iii. In height: above the ground, not less than 250 mm, not more than 2100 mm. iv. Rear Position lamp may have parts in common with any other lamp situated at the rear.	
2.	Reversing lamp	2/Rear/White
	Position / Arrangement i. In height: above the ground, not less than 250 mm nor more than 2100 mm ii. They shall be such that the lamp can light up only if the reverse gear is engaged. iii. Reverse lamp may have parts in common with any other lamp situated at the rear	
3.	Direction indicators	2/ Rear/ Amber
	Position / Arrangement i. The point on the illuminating surface farthest from the median longitudinal plane of the trailer shall be not more than 500 mm from the extreme outer edge of the vehicle ii. The distance between the inner edge of the two illuminating surfaces shall be not less than 500 mm. This distance may be reduced to 400 mm, where the overall width of the trailer is less than 1300 mm. iii. In height: above the ground, not less than 250 mm nor more than 2100. iv. Rear direction indicator may have parts in common with any other lamp situated at the rear. v. The direction indicator flashes in unison at a rate of 60 to 120 flashes per minute. vi. The direction indicator shall be designed and fitted so that the tractor operator knows that it is operating correctly (tell-tail).	
4	Stop lamp (Brake lamp)	2/ Rear/ Red
	Position / Arrangement i. The point on the illuminating surface farthest from the median longitudinal plane of the trailer shall be not more than 500 mm from the extreme outer edge of the vehicle. ii. The distance between the inner edge of the two illuminating surfaces shall be not less than 500 mm. This distance may be reduced to 400 mm, where the overall width of the trailer is less than 1300 mm. In height: above the ground, not less than250 mm nor more than 2100 mm. iii. Stop lamps may have parts in common with any other lamp situated at the rear. iv. All stop lamps shall light up simultaneously when the braking system operates	

The trailer was fitted with two turn indicators (Direction indicators) lamps on the rear side. The light emitted by lamps while in operation was visible from both the front and rear of the vehicle. The illuminated area of each direction indicator was not less than 2250 mm^2. The brake-operated stop light was provided at the rear of the trailer, which emits red light intended to warn of the slowing down or to stop of the vehicle, the stoplights were provided as part of tail lamps.

Results and Discussion

Wireless communication was used to transmit process data and operation commands between the agricultural vehicles, and a data protocol was developed to operate the indicators. Almost 50% of the drivers either fail to indicate while changing lanes or do not turn the indicator off. While failing to indicate a turn might seem like a small violation, several accidents are caused while turning without indication or during lane changing. The respective operator gets an ON/OFF indicator light based on the steering angle. This wireless signal will be useful when the driver/rider put the indicator while entering the road from parking, during U-turn, reversing the vehicle, both the indicator light will be ON. Taillight set was made up of ABS plastic with four chambers. The input voltage was 24 V. The operating power was 10 watts with a 9 Amp current.

Fig 8: Evaluation of RF wireless setup

A list of the functions that the system can perform, or rather

types of information that can be displayed with the current taillight configuration, includes only the following items: (a) braking information, on-off; (b) running information (absence of braking), on-off; (c) turning information, left-off-right; and (d) backing information, on-off (Anon.). It was observed that the maximum angle at which the trailer wheels start rotate in a 50° of the steering angle, if the straight position of the wheels is considered to be at 90°. This angle also depends on the make and dimensions of the vehicle. The ergonomic evaluation of the vehicle drivers (subjects) is recorded based on the actual road condition for the effectiveness of the indicators in the trailer, as shown in Figure 9. Each subject drove five runs, and each run lasted about 15 minutes. Before the experiment, the subject was not intimated about the experiment with the driving task, in order to extract the best results. This study showed that an indication of light signals during a driving task has a large adverse effect on preventing accidents. On average, the reaction time increases with 240 ms of a driver. The reason for this significant increase in reaction time is that the light creates attention to detect movement precisely presented at the roadway. From Figure.9, it is recorded that only 20 percent of the drivers can predict the trailer direction without tail light indication. After installing tail lights in the trailers, 100 percent of the drivers can visualize and drive accordingly. The flashing lights have more attention attraction properties than continuous lights, especially when they appear in the periphery of the visual field (Gail *et al.*, 2001) [4]. The light intensity was the reason for this adverse high-frequency behavior and a good predictor of the performance ranking.

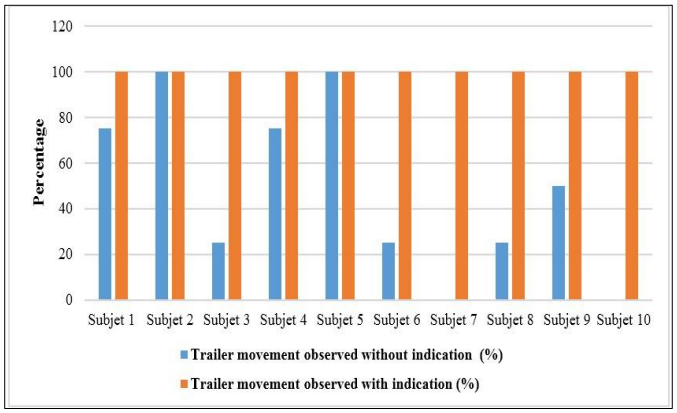

Fig 9: Ergonomic analysis of vehicle driver's comfort

Conclusion

The signal functions of a vehicle represent an important contribution to road safety as they show other road users the current driving condition of the vehicle. Any vehicles ahead, braking, or reversing are made visible to other road users by means of the respective signal function. Hazardous situations, such as driving in fog or emergency braking, are highlighted by special signal functions (Mugge and Hohmann, 2016) [9]. In such a way, tractor-trailer safety is commonly measured in terms of the frequency of accidents and the consequences of these accidents with regard to their outcome in terms of severity. The specific safety problems were identified as the indication of the movement of the tractor cum trailer to the other vehicle, which is in front and back of the tractor. When the indication is available to the destination before a certain turning distance, this will help people avoid accidents during rush hours and emergency situations.

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Conflict of Interest

The authors declare no conflict of interest.

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