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SPEED PROFILE AND DELAY OF VEHICLES PASSING THROUGH AT-GRADE RAILROAD CROSSINGS

Siradol Siridhara and Onanong Sangphong

Suranaree University Of Technology,Thailand

Thailand has been replacing at-grade railway crossings with various types of separate-grade facilities. The economic benefits were justified socially but had never been explored quantitatively. Drivers decelerated upon approaching the railroad crossings and then accelerated back to normal speed upon leaving. This research recorded changes of vehicle speed when passing through at-grade railroad crossings. The speed profile was used to assess economic loss due to delays in travelling to and from work. Data were collected from at-grade crossings with different supporting materials including concrete paved, asphalt paved, and wooden boards in urban and suburban areas of a major northeastern province of NakhonRatchasima where a large number of trains run through daily. The space mean speed (SMS) data collected from these three types of crossing were as follows: SMSAsphalt = 25.91 km/hr, SMSConcrete = 19.41 km/hr, and SMSWooden = 16.37 km/hr, respectively. Further study determined delays occurred by approaching different types of crossings paving materials as a function of traffic volume measured in vehicle per hour (veh/hr). The resulted delays including waiting time for trains to pass were converted to economic loss in monetary value. Annual losses for each type of crossing were estimated as a referenced value for economic feasibility analysis of future separate-grade railway crossing projects.

Keywords: Speed, Delay, Railway, At-grade crossing, Economic loss.

Introduction

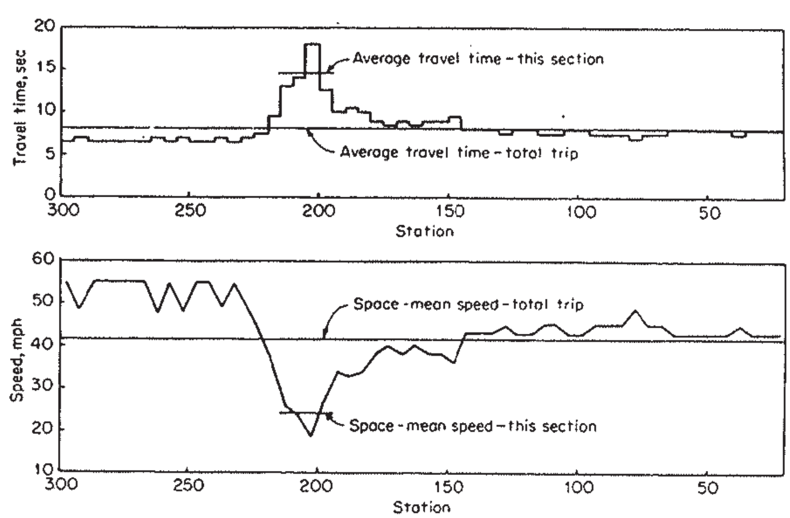
Railway in Thailand consists of four main routes spreading out radially from Bangkok: the northern line, the north-eastern line, the eastern line, and the southern line. These railway lines serveurban rural communitiesand had become the main transportation mode for a long time. However, after the development of highways and major roads throughout the country, railway became an obstacle to connecting roads to these communities. In addition to main roadsthat for at grade crossings with the railway in various places, effortshave also been made to illegally build small road connections between communities on opposite sides of therailways. These local crossings were usually developed into a more proper rail cross later.Because these rail crossings are numerous and the funds for construction are limited,improvingthe pavement at the intersection is thus considered important. Three types of road surface treatmentsinclude concrete, asphalt, and wooden surfaces.Concrete type is often used on major roads in urban areas with heavy traffic volume. Asphalt and wooden types are used for road surfaces in areas outside the city, whichare often on two-lane minorroads. Vehicles traveling through these rail crosses will be forced to slowdown to maintain the comfort level. This cause travel delay and a risk of rear-end collision accidents.

Despite the fact that Thailand has a huge number of at-grade railroad crossings, no research on of motorist behaviour crossing and speed profileacross the railwaywere never been conducted.The study would offer estimation on economic loss and benefits should an overpass was constructed.Oktsu[8] proposed a methodfor estimation of time loss caused by stopping at the railroadcrossings using a simple queuing theory (Deterministic Queuing).

The railway development master plan[5] and detailed design[4]studies in Thailand considered the cost of passingthroughthe at-grade rail crossing in form of time wasted while waiting for the train as well as the cost of damage caused by accidents. Nonetheless,they did not takeinto accountreductionof speed at the at-grade rail crossings due to the lack of information andreliable reference.This research studied the patterns of driving speed while crossing therailroad on different types of surface, and ananalysis oneconomic loss due to inability to drive at a normal speed. The results would be used as the basis for modelling the prototype vehicle that ranthrough the rail crossingsin the microscopic level and estimate economic benefits when overpasses were built.

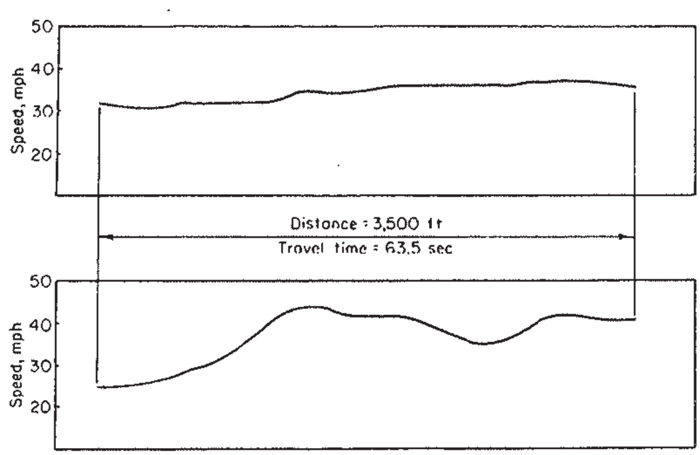
Literature Review

Highway Level of Service (LOS)based on the theory of the U.S. Highway Capacity Manual[7]is determined by thecomfort of the drivers which is typically measured by congestion or travel time. However, prior to setting the level of service standard in 1965, other forms of highway performance measure had also been considered. Drew[6]pointed out thattravellingtime alone could notalways reflect convenience of travel. He demonstrated how measures of level of service should be determined based on the difference in travel time and average speed as shown in Figure 1. He alsocompared two trips with the same distance and travel time but different levels of comfort asshown in Figure 2.



Source: Traffic Flow Theory and Control (1968)

Figure1 *A Comparison of Travel Time and Speed in a Short Distance and the Entire Trip.*



Source: Traffic Flow Theory and Control (1968)

Figure 2 *A Comparisons of Levels of Convenience due to Speed Variation.*

Brindle[2] showed a collection of speed data at each point on minorroadsin order to determinetraffic calming strategy by using speed as a measure. This study showed the calculation of the speed differential and proposedtwenty kilometres per hour as a critical value for safety of the following car.The speed study generally used traffic speed chart to analyse the performance indicators of each type. Barbosa et al[1] conducted experiments and plotted speed data from different roads which are installed with traffic calming devices by estimating the spot speed from data collected by a pneumatic tube and determined relationship among speed at various points with the initial velocity, types of traffic calming devices, and installation distance, in the form of a cubic equation. It was noted that the width of the road and particular environment conditions may have played important roles in reducing or increasing the speed of the car.Pau and Angius[10] tested the performance of the speed humps on roads in the city of Cagliari, Italy and found that the speed humps did not play significant role in speed reduction on the roads with narrow lanes.The Institute of Transportation of the State of Texasalso found that installation ofwarning signs in various forms before the at-grade rail crosses didnotreduce speed at all[9]. However, no studies were conducted to test the effect of the road surface or railway crossing on the speed of vehicles by using the speed chart.

Methodology

Speed data were collected in areas of NakhonRatchasima Province. Three main survey pointsincluded: 1. Nong Pet Nam Railroad Crossing, 2. Sueb Siri Road, and 3. the Chainarong Railroad Crossing. Speed data were collected by speed gunsevery five meters from the centre of the rail track on both sides until thirty meters from the trackfor both directions (Figure 3).Three types of rail crossing including wooden surface (Figure 4), asphalt surface (Figure 5), and concrete surface (Figure 6) were representatives for each of the study locations.

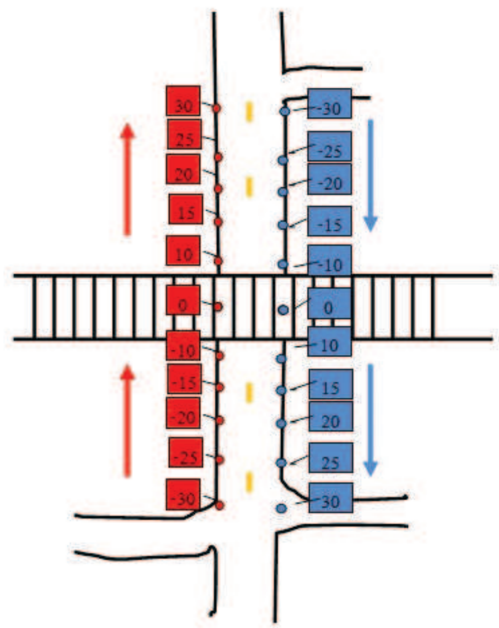
Figure3: Speed Capture of the Vehicles.

Figure4: Wooden Surface Rail Cross(the Nong Pet Nam Rail Cross).

Figure5: Asphalt Rail Cross (The Sueb Siri Rail Cross).

Figure6: Concrete Rail Cross (The Chainarong Rail Cross).

Time Mean Speeds (TMS) or spot speedwas average speeds at a given point which provided meaningful data for speed profile. The TMS were collected on both directions during 09.00 AM - 15.00 PMon weekdays on all study sites. The data recording form was as shown in Figure 7.



No.	type		station					
	MC	CAR	-30	-20	-10	10	20	30
1								
2								
3								
4								
5								
6								
7								
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9								
10								
11								
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Figure7: Positions and Data Recording Form.

This study aimedto determine the difference ofnormal speeds and the railroad crossing speeds. The speed profile was plotted and the delay was estimated. The influenced area of the speed reduction was tested by comparing the average speed at the two adjacent locations via the paired t-test.Economic loss was determined by converting delays into time lost which was caused by speed reduction through railroad crossings. The analysis for average speed of each road was carried out for both direction in form of Space Mean Speed (SMS) or average speed through a given section.

Findings

Comparison of Speeds among Rail Crossing Surface Types

The speed of a given vehicle was assumed independent of traffic condition, i.e. not affected by the vehicle in the front or in the back. The average driving speed (TMS) for all railroad crossing surface types is shown in Figure 8. Based on the whole 60 meters section, SMS was estimated by the following formula

Where $v_i$is the average time mean speed(TMS)at each position

It was found that the speeds of the asphalt, concrete, and wooden surfaces were 25.91, 19.43, and 16.37 kilometres per hour respectively.

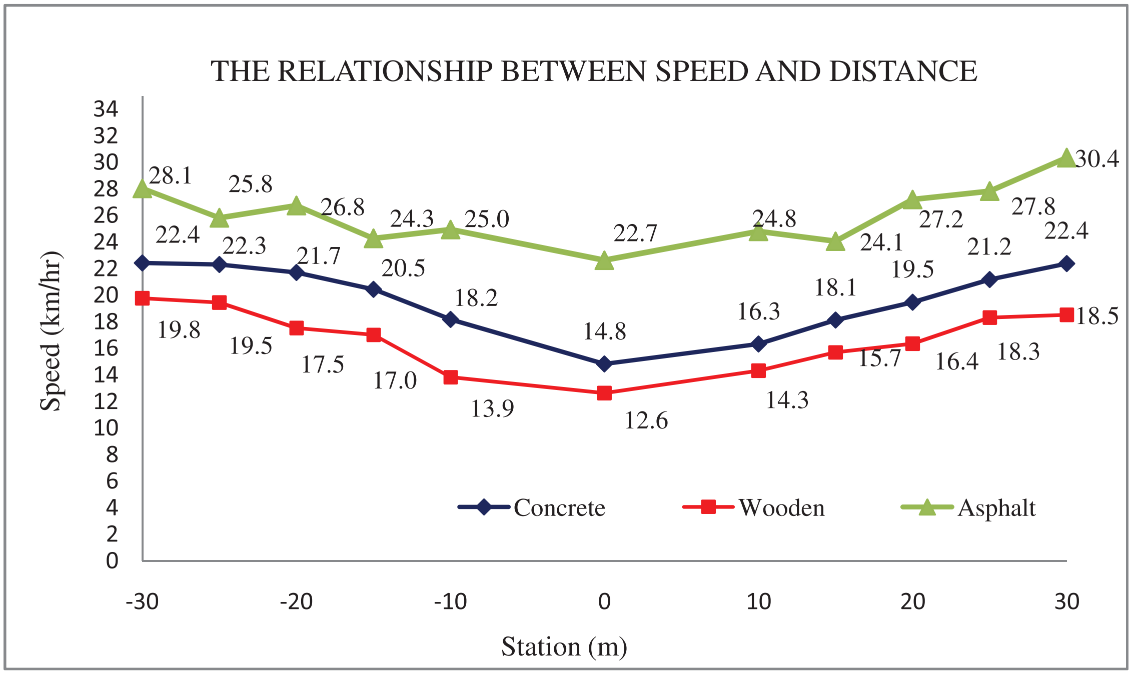

Figure8: Spot Speedsat Different Position from Railroad Crossing.

Comparison of Speeds among Stations

Analysis of driving speedsbetween the pair-t-testdeterminesless than 0.05 level of significanceas shown in Table 1 below (at a level of confidence 95 percent). This indicatedthat there wasmajordifference between speeds from each adjacent station. In other words, speed drop and gain was evident. Positive t-values meant speed drop and negative t-value showed speed increase. Significant speed difference was found until the last station which meant that the influence area of the speed drop would cover farther than ±30 meters from the track.

Table 1: Comparison of speeds before and after crossing the railroad on the concrete surfaces.

Paired Differences		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	Sig. (2-tailed)	Results of Speed Comparison station
					Lower	Upper			
Pair 1	st -30 - st -25	-.203	2.600	.214	-.625	.220	-.948	.345	=
Pair 2	st -25 - st -20	.675	2.763	.225	.231	1.120	3.004	.003	>
Pair 3	st -20 - st -15	1.293	3.229	.266	.766	1.819	4.853	.000	>
Pair 4	st -15 - st -10	2.326	2.582	.215	1.901	2.752	10.810	.000	>

Pair 5	st -10 - stcenter	3.844	5.720	.492	2.871	4.818	7.810	.000	>
Pair 6	stcenter - st 10	-1.432	5.224	.443	-2.308	-.556	-3.231	.002	<
Pair 7	st 10 - st 15	-1.865	3.234	.266	-2.390	-1.340	-7.015	.000	<
Pair 8	st 15 - st 20	-1.308	2.400	.190	-1.684	-.932	-6.874	.000	<
Pair 9	st 20 - st 25	-1.108	2.797	.230	-1.563	-.654	-4.819	.000	<
Pair 10	st 25 - st 30	-.576	2.554	.228	-1.028	-.124	-2.522	.013	<

The driverswould reduce the speed before reaching the rail crosses and accelerate until the normal speed was obtained. Asphaltic surface would maintain rather smoother speed profile than the two others. The speeds did not only depend on the types of crossing surface but alsoon the physical characteristics of the road for instance intersections, roughconditions (bumpy or smooth).

Analysis of Loss due to Delays

Vehicles crossing railroadswould slow down in order to maintain the engine and the comfortable level.Speed reduction caused loss in the form of delays andrisk of rear-end collision accidents. Delays could be estimated by the following equation:

$$delay = \frac{d}{(v_{FFS} - v_{SMS})x10^3}\, n$$

Where d = Analysis distance (meters)
V_{FFS} = Free Flow Speed (km/hr)
V_{SMS} = Space Mean Speed (km/hr),
n = daily traffic volume (vehicles per day)

Delayson the asphalt,concrete, and wooden surfaces werecalculated as0.011783n, 0.013138n, and0.016522n hours per day respectively where n is a number of vehicles per day.It could be concluded that travelling through the wooden surface caused most time loss followed by concrete and asphalt surfaces respectively. Analysis of economic loss for example when the road has a traffic volume of 1,923 vehicles per day (based on the average traffic volume of rural highway network in Ratchasima Province, 2553)[3] and the Provincial value of timeof0.64 dollars per hour[11], delays due to passing through the rail crosses on the concrete, wooden, and asphaltsurfaces will result in economic losses of 153, 193 and 137U.S. dollars per dayor 50,500, 63,700 and 45,200 U.S. dollars per year respectively.

Discussion and Conclusion

The travel speed profile was used to describe the convenience of driving.It was found that crossing onthe asphalt surface provided the most comfortable feeling followed by the concrete and the wooden surfaces respectively. The vehicles would slowed down before reaching the rail crosses with minimum speeds at the tracks before being accelerated again upon leaving in order to obtain normal speeds. The speeds before and after crossing the rail crosses are significantly different at aninety-five percent confidence level. The influenced area expanded beyond 30 meters from the track. In addition, not only did the types of surface play an important role but the physical characteristics such as conditions of the roads, intersections, numbers of traffic channels, and various warning signs also played the part as well.

Economic loss due to inability to obtain normal speeds when crossing the at-grade rail crosses depended on the amount of traffic volume on thatparticular route and the value of time of the people in the province. Statistics showed thatNakhonRatchasimapeople received an average income of 0.64 dollars per hour. Thus crossing on the wooden surface would result in the most loss of income (193 dollars per day) followed by the concrete surface (153dollars per day), and the asphalt surface (137dollars per day) respectively.

This research studied driving speeds which were independent to each other. The study focused on estimation of economic loss due to time wasted at the railway crossing. However, other types of economic loss should be investigated including vehicle operating costs, accident risks and environment impact. Also a feasibility study of railway overpass could not be completed without considering impact to community in the vicinity. These components needed to be considered in order to evaluate true economic impact and create a basic standard for feasibility study of the railway overpass project in the future.

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