



Review of Track Gauge for Trans-Sumatera Railway Revitalization and Development

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Diterima: 4 Maret 2020, Direvisi: 26 Juni 2020, Disetujui: 30 Juni 2020

ABSTRAK

Tinjauan Terhadap Track Gauge Dalam Rangka Revitalisasi dan Pengembangan Perkeretaapian Lintas Sumatera: Tujuan penelitian ini untuk memahami secara detail dan komperhensif bagaimana revitalisasi dan pengembangan infrastruktur jalan kereta api pada jalur Trans-Sumatera di Pulau Sumatera. Masalah utama dalam penelitian ini, bahwa penggunaan kereta api di Pulau Sumatera tersebut tidak berkelanjutan pada semua provinsi. Penelitian ini merupakan suatu meta analysis dengan melakukan eksplorasi dari jurnal-jurnal yang ada ataupun faktual sebagai fenomena pada penggunaan lebar rel kereta api yang terjadi di dunia saat ini. Dilengkapi dengan parameter atau indikator kinerja, sebagai benchmarking dengan negara lain. Dari hasil penelitian ini, data menunjukkan bahwa hampir 60 persen dari jalur kereta api yang ada di seluruh dunia telah dipasang dengan ukuran standar 1,435 mm dan merupakan standar internasional. Manfaat dari penelitian ini, bahwa para pemimpin atau pengambil keputusan dapat memperhitungkannya untuk mendukung transportasi masa depan di Pulau Sumatera yang harus berorientasi pada kondisi yang lebih besar, lebih cepat, lebih aman, lebih bersih, lebih murah, terjangkau, dan kenyamanan. Untuk terus mengeksplorasi kereta api atau lintasan yang ada, dapat dilakukan dengan mengembangkan peralatan konstruksi pengubah lebar rel untuk mengubah lebar rel roda kereta api dari 1,435 mm menjadi 1,067 mm. Selanjutnya dilakukan pengukuran ulang secara bertahap, mengubah lebar rel dari 1,067 mm menjadi lebar rel standar 1,435 mm.

Kata Kunci: lebar rel internasional; lebar rel Iberian; lebar rel sempit; lebar rel standard; jalur Trans-Sumatera; pengubah lebar rel.

ABSTRACT

The aim of this research is to comprehend in details how revitalization and development of railway infrastructure on the Trans-Sumatera line in Sumatera Island. The main problem in this research is that the use of railways in Sumatera Island is neither sustainable nor in all provinces. This research is both meta-analytical, by exploring the existing journals, and factual as a phenomenon in the utilization of spoor width that happens in the world today. It is completed by parameter or performance indicators as for benchmarking with other countries. From the result of this research, the data shows that almost 60 percent of existing railway tracks around the world have been installed with standard gauge of 1,435 mm and have been international standard. The benefit of this study is that the leaders or decision makers can take it into account to support the future transportation in Sumatera Island which must be oriented to bigger, faster, safer, cleaner, cheaper, affordable, and leisure. To keep exploiting the existing railway or track can be done by developing construction equipment of track gauge adjuster to change the wheel gauge from 1,435 mm to 1,067 mm. Subsequently re-gauging is done in stages, changing the track gauge from narrow gauge of 1,067 mm to standard gauge of 1,435 mm.

Keywords: broad gauge; iberian gauge; narrow gauge; standard gauge; Trans-Sumatera line; track gauge adjuster.

I. Introduction

In the operation of railway with with track gauge of 1,067 mm, the main limitations are the axle pressure which influences the load capacity and maximum operation speed which has impact on the load capacity including train circulation time

and railway coach. The operation of a train with standard gauge of 1,435 mm which has heavy axle pressure and high maximum speed will make the load production capacity higher, productive and very efficient. In the era of Industrial Revolution 4.0 today, actually the

philosophy of transportation saying that today's transportation must refer to the philosophy of future transportation, i.e. bigger, faster, safer, cheaper/affordable, leisure. So, the railway with standard gauge of 1,435 mm is very appropriate. Therefore, the planning of both infrastructure and rolling stock should follow the principles of future transportation philosophy. The development of future railway network is no more directed to the railway with gauge of 1,067 mm, even a railroad expert in China says that the number of narrow gauge of 1,067 mm will decrease in the future. The development of future railway network will always be oriented to high speed so, like it or not, it must be developed with standard gauge of 1,435 mm. With the technological advancement today there has been no problem of connection to other routes using different gauges since it can be overcome by using the technology of Track Gauge Adjuster.

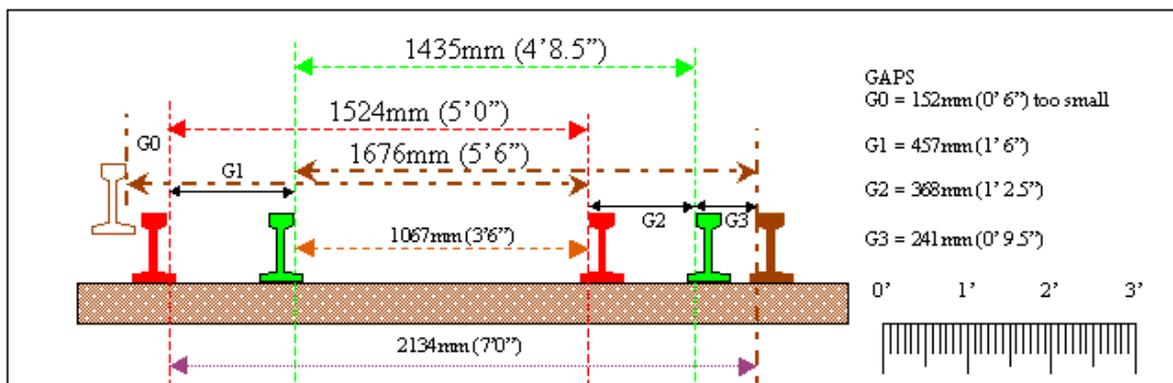
There are four sizes of main gauge used in Europe, namely narrow gauge of 1,067 mm, standard gauge of 1,435 mm, broad gauge of 1,520 mm, and Iberian gauge of 1.668 mm (Figure 1). The use of narrow gauge (1,067 mm) in the world today amounts 10.49 percent, standard gauge (1,435 mm) amounts 67.45 percent, whereas broad gauge and Iberian gauge (1,520 mm) amounts 22.06 percent. There is a special category in Europe with track gauge almost the same as in Russia, i.e. 1,524 mm in Finland and then is followed by Estonia.

Narrow gauge track (1,067 mm) is technically designed to have maximum speed only up to 120 km/hour and axle pressure not more than 20 tons. Likewise, the size of Locomotive, train and carriages is relatively small since it is limited by the existence of axle pressure. The manufacturers of rolling stock for narrow gauge of 1,067 mm are very limited, so it must be special order. Track with standard gauge of 1,435 mm is technically designed for maximum speed up to

higher than 250 km/hour and even in China the speed in the trial reached 400 km/hour. Axle pressure can be designed from 20 to 30 tons, so the size of locomotive, train and carriages is bigger, giving impacts on the load capacity to become higher. The manufacturer of Rolling stock for standard gauge of 1,435 mm has many choices because the users of such a railway type spread all over the world.

Some thoughts on railroad planning on Trans Sumatera route are; (1) Does the development of Trans Sumatera Railway use track gauge of 1,067 mm (narrow gauge) or track gauge of 1.435 mm (standard gauge) and (2) If Trans Sumatera Railway to be developed using standard gauge of 1.435 mm, then how to overcome/utilize the existing track with narrow gauge of 1,067 mm which has track of 1,150 km? The aim of this research is to analyze and know in detail and comprehensive ways the infrastructure development plan in the form of railway on Trans-Sumatera route, whether it must use gauge of 1,067 mm or standard gauge of 1,435 mm in relation to the future railroad development plan. This study only discusses the comparison between the use of railway track with narrow gauge and standard gauge, no calculation of construction and maintenance costs involved; whether relating narrow and standard gauges gives impacts that make standard gauge inefficient since the train deadload is determined by narrow gauge so that there will be economically and financially different scenarios.

Fourie & Zhuwaki, (2017) explain a framework to implement the reliability-based technique in order to evaluate the reliability of train infrastructure system through qualitative approach with modelling infrastructure dependencies. Coombe et al., (2016), in a research using qualitative approach, develop a double gauge track with three rails to enhance the connection of and delivery traffic between



Sources: Starns, 2012

Figure 1.
Comparison of Track Gauges.

different tracks and with other parts of Europe. Another research using qualitative approach shows that infrastructure manager should consider the specialization of track gauge type when determining the minimum gauge radius (Popović, Lazarevic, & Vatin, 2015). Research by Purwanto, (2008) examines concrete bearings for railway track in Sumatera with standard gauge of 1,435 mm using test standard of AREMA (America Railway Engineering and Maintenance of Way Association). Another research studies the standard gauge of 1,435 mm with the international standard used for high speed tracks in Spain and North America (Cuadrado, et al., 2008; Puffert, 2000). In 2006 Trans-Asian Railway Network Agreement was ratified (Gross, 2016). The countries being part of or affected by Trans-Asian Railway Network Agreement when it was ratified are South Korea, North Korea, China, Iran and Turkey. Their railway standard uses standard gauge of 1,435 mm. Today, throughout South Korea and most of North Korea also use standard gauge of 1,435 mm (Cha, Bermudez, & DuMond, 2018).

II. Research Methodology

This research is of meta-analytical, by exploring the existing journals, and factual as a phenomenon in the utilization of spoor width that happens in the world today. This research is also completed with performance parameter or indicators, concerning what is used for benchmarking with other countries. Performance indicators are used more than once, so each alternative can be seen in the advantages of using standard gauge and the disadvantages of using narrow gauge. Some technological indicators and organizational solutions to transfer passengers and goods from one type of gauge to another transportation (SzkodA, 2014), are such as bogie change, gauge change system, and passengers have to change the train, and goods are to be loaded (Gailienė, Gedaminskas, & Laurinavičius, 2018). It is especially the indicator of relations between track with bogie system and Rolling stock wheel. This study uses several sources of research related to railroad track gauge, literature study as well as national and international scientific journals as the basis for studying the operation pattern of Trans Sumatera Railway. It uses the comparison of some track gauges between narrow gauge and standard gauge which are used in many countries around the world, such as Europe, Asia, North America and Africa in the period of 2018-2019. Discussion is also made in more detail about the comparison of gauge change from standard to broad gauge

between in Europe and in Iberia as well as the use of gauge width between Europe and Finland or Russia and the fractions of ex Soviet Union where there is no track change between narrow (1,067 mm) dan standard gauges (1,435 mm).

III. Results and Discussions

A. Selecting Track Gauge for Future Railway Track

1. The use of standard gauge of 1,435 mm in Europe

Majority countries in Europe use gauge tracks of 1,435 mm (Hilton, 2006; Gailienė et al., 2018). Great Britain is actually the first country that develops modern train, giving impacts to all over the world. Various types of track gauges are used for train in the last time were developed in the district of mining during the end of eighteenth century, with gauge of 1,422 mm (Puffert, 2002). Initially Britain developed track gauge of 1,435 mm since it uses the same system and equipment while developing tram line, then it moves on to use broad gauge and this is followed by Ireland (1,600 mm) (Post, 2014; (Marian, 2019). The most widely-used gauge in the world is standard gauge of 1,435 mm. It is used in most countries, contributing 67,45 percent of railroad network in the world. In general, the last type is compatible with the train built for gauge of 1,520 mm and gauge of 1,600 mm used in Ireland and North Ireland, and Iberian gauge of 1,668 mm used in Iberian Peninsula (Marian, 2019). Standard Gauge is also the main gauge in most European countries (France, Germany, Italy, Greece, Britain, Poland, Switzerland, Austria, Denmark, Sweden, Norway, etc.) (Alvarez, 2010). Track Gauge with more types are used in Belarus, Estonia (old tracks), Latvia, Lithuania, Moldova, Russia, Ukraine (gauge of 1,520 mm) (Hilmola, 2011; Gailienė et al., 2018; Marian, 2019), in Finland and Estonia (1,524 mm); in Spain and Portugal (1,668 mm) (Gailienė et al., 2018). Another route, according to Wong, Chin, & Kuik, (2018), is the railroad connecting Kazakhstan-Russia and Belarus which also uses gauge of 1,520 mm. In another part of Eastern Europe, Ukraine uses both standard gauge (1,435 mm) and broad gauge (1,520 mm). The change of track gauge use in Eastern Europe to the gauge of 1,520 mm is because the average speed for passenger trains is planned to be 170 km/h, and top speed in best sections 240 km/h (Kakulis, 2011). Finland dan Estonia are new tracks using the gauge of 1,524 mm (**Figure 2**) (Marian, 2019). Both of these countries use 90-tonne locomotive from Germany. Each of the four-



Sources: Marian, 2019

Figure 2.
Public Railways Track Gauge.

axles of the 90-tonne locomotive rests on a separate buggy allowing transport of the broad-gauge unit on standard-gauge tracks without dismantling large sections beforehand (Smith, 2015). The undersea standard-gauge tunnel will significantly reduce travel time between Finland and Estonia from two hours by ferry to 40 minutes by train, and is expected to create a unified metropolitan area (Burroughs, 2019).

Spain is the biggest user of gauge system railway, and has railway networks with different tracks; i.e. standard gauge (1,435 mm), Iberian gauge (1,668 mm), and dual gauge (with three rails), which is now used widely in the high speed network (Domingo, et al., 2018; Gailienè et al., 2018; Almech et al., (2019). Nevertheless, the 1,000 mm and 1,067 mm network is not considered here. All new railways in Spain have been built using double track and the best technology, and no more use narrow gauge because no rolling stock can run on the narrow gauge track (Villalba et al., 2017; Almech et al., 2019; Adif-Fichas Informativas, 2019). In Spain, double track with standard gauge (1,435 mm); built with specifications; electrified double track; electrified single track. While, Iberian track gauge (1,668 mm); built with specifications; electrified double track; electrified single track; nonelectrified double track; nonelectrified single track. This is because of the need for connecting the older main route constructed using Iberian

gauge system and high-speed railway track to connect with France using standard gauge of 1,435 mm (Alvarez, 2010). The lack of interest in international standardization according to the study by Puffert, (2002), is obviously proven in the gauge implementation in Europe since the beginning. Different standards and the size of wider than 1,425 mm are found such as in Germany (1,600 mm), Russia (1,524 mm), and Spain (1,668 mm). Especially in Russia and some ex Soviet Union countries, there are differences in the use of rolling stock, coupler equipment, bolt size, hydraulic testing so that their track gauge (1,524 mm) is different from the other countries in Europe (Belyaev, 2013).

2. The use of standard gauge of 1,435 mm in North America

Since long time ago, railways in the United States generally use standard gauge of 1,435 mm, because they were built by British expatriates (Post, 2014). In the end of nineteenth century most railways tracks in the United States have changed to be standard gauge of 1,435 mm. This is triggered by the increase of demand for train in North America and the increase of cooperation among railroads resulting in incentive to complete the various usage of track gauge and regional gauge directing to the selection of standard gauge of 1,435 mm as the continental standard (Puffert, 2000; Puffert, 2002; Hilton, 2006). The use of standard gauge of 1,435 mm in

American continent has also become the main choice. In the progress up to now, some cities in the United States are using track gauge wider than 1,435 mm, such as in Pennsylvania, Norfolk and Richmond to Memphis and New Orleans (Hilton, 2006).

3. Rest of the World

3.1. The use of standard gauge of 1,435 mm in Asia and Australia

The patterns of gauge selection in Latin America, Africa, and Asia were introduced in 1860s with the use of Stephenson gauge and the areas where train is introduced subsequently adopt Stephenson gauge or narrower gauges (Puffert, 2002). In the territory of Asia, Trans move on the Russian gauge track (1,520 mm), encountering the standard gauge (1,435 mm) lines in China and Korea again (Gailiené et al., 2018). On the Transmongolian Railway, Russia and Mongolia use 1,520 mm, while China uses the Standard gauge of 1,435 mm. Japan, as a mountain country, builds conventional railway using narrow gauge of 1,067 mm, but some routes use standard gauge (1,435 mm) (Semmens, 1997). When performing experiments to enhance the operation speed in the era of electric-powered train, narrow gauge proves to be disadvantageous for mountain area, which hinders the increase of train travel speed. The existing high speed trains in Japan is initially of increased speed on the existing railway with standard gauge of 1,435 mm (Mochizuki, 2011). Subsequently all infrastructure will be developed for Shinkansen standard with high speed, namely standard gauge of 1,435 mm, with minimum radius 4,000 m. Whereas in Australia in the early 1850s, for the first time South Wales chose the gauge wider than 1,435 mm that is 1,600 mm, followed by Victoria and South Australia to use the same standard (Puffert, 2002; Warwick & Cruse, 2014; Trainline 7 statistical report, 2019). Australia is developing the technology of track gauge to reach higher speed and with heavier load transport (Indraratna, Nimbalkar, & Rujikiatkamjorn, 2012). Whereas Australia's close neighbor, New Zealand, still uses narrow gauge (1,067 mm) since this country does not yet need higher speed railway (Post, 2014).

3.2. The use of standard gauge of 1,435 mm in Africa

Some master plans including the development of new routes in Africa using standard gauge and metric gauge conversion toward train modernization has become the main choice. The existing metric gauge network can be

rehabilitated and implemented for future projects with financial investment through private sector participation supported by strong commitment from the government to accommodate high speed train in the existing network. The conversion from metric gauge to standard gauge of 1,435 mm is economically feasible and more profitable with multistage investment (Minsili, et.al., 2017). Standard gauge of 1,435 mm is also used for railway in Kenya. Especially in Kenya, China strongly supports the development of Standard Gauge of 1,435 mm (Wissenbach & Wang, 2013; Irandu, 2017). In western Africa, the use of narrow gauge of 600 mm also changes to the use of standard gauge (1,435 mm) (Bayane, Yanjun, & Bekhzad, 2020). Indeed, railways in Africa have not many yet but the use of standard gauge of 1,435 mm has become the main choice.

4. The advantages and disadvantages of using narrow gauge and standard gauge

The advantages of track with narrow gauge of 1,067 mm are that it can be developed with small radius, smaller structure, lighter rail, smaller bridge and tunnel, use of smaller and light rolling stock so the costs of development is cheaper, thus bigger saving so that it will be very good to be used for mountain areas (railsystem.net, 2019). Another advantages, land savings when the available area is limited and smaller scope of work compared with two gauges (Gailiené et al., 2018). The weaknesses of railway with narrow gauge of 1,067 mm are that it is difficult to be developed either for maximum speed, for increasing axle pressure, load capacity or stability when double decker train is operated. Some disadvantages based on (Gailiené et al., 2018), such as, (1) most of special materials are in limited availability; (2) limited material, double track is more expensive, this is also important when spareparts are needed during the operation; (3) track construction machines are to be fit for non-standard structural solutions; (4) platforms cannot be installed at one side of such track; (5) lack of standard for the design of dual tracks.

5. The philosophy of current and future transportation

In order to accommodate the desire to realize the dream for future transportation system which is always directed to bigger, faster, safer, cheaper/affordable, leisure, the track gauge selected to use is standard gauge of 1,435 mm. From the above description and based on the usage number of standard gauge of 1,435 mm around the world which reaches 67,45%, more than half of track gauge used in the world, it

means that use of standard gauge is a right choice to welcome the current and future transportation.

B. Choosing Track Gauge for Trans Sumatera Railway

Sumatera Island stretches from west to east with the westernmost city in Aceh Besar district Kota Raja and the easternmost city in South Lampung district Bakauheni (**Figure 3**). The distance between those two cities (districts) reaches 2,270 km, a far enough distance. If those two cities are connected by high speed railway with average speed of 250 km/hour, the travel time is around nine hours. This is the same with the travel time from Jakarta to Surabaya by Argo Bromo train. Considering the potential carriage of both passengers and goods and the distance between Banda Aceh city in North Aceh and Bandar Lampung city in South Lampung as far as 2,270 km, the very effective and efficient transportation mode should be taken into account so that the national efficiency can be realized. Therefore, it is necessary to immediately carry out the development of Trans Sumatera Railway. To make this dream come true, one thing must be paid attention, namely track gauge selection on the track of Trans Sumatera Railway.

The comparison of land use for constructing the railway with track gauge of 1,067 mm and the railway with track gauge of 1,435 mm (Perhubungan, 2012) is as follows; (1) Free space for double track at both straight and curve lines is

the same, (2) Maximum speed designed for the gauge of 1,067 is 120 km/hour whereas for gauge of 1,435 mm is 170 km/hour or more, (3) The distance of building space for the gauge of 1,067 mm is 2.35 m from the spoor axle and for gauge of 1,435 mm is 2.55 m so the difference is only 20 cm, and (4) The smallest curve on gauge of 1,067 mm is 100 m whereas for gauge of 1,435 mm is 250 m. To start implementing that idea, in the fiscal year 2006/2007 the Government, in this case Ministry of Transportation c/q Directorate General of Railways has carried out railway development project in Aceh Province starting from Lhok Seumawe city to Sigli using the spoor width design (track gauge) of 1,435 mm as long as 11.3 km. Considering the description of track gauge selection for Trans Sumatera Railway, the Track Gauge selection for future railways and the philosophy of today's/current and future transportation, then the use of track gauge of 1,435 mm is the most appropriate choice for Trans-Sumatera Railway.

C. The Optimization and Revitalization of Existing Track Using Track Gauge of 1,067 mm in North Sumatera, West Sumatera and South Sumatera

Sumatera Island has had a development program of Trans Sumatera Railway which will connect two big cities, namely Bakauheni in South Lampung district and Kota Raja in Aceh Besar district which is about 2,270 km away. Today,



Sources: *Perkeretaapian*, 2011

Figure 3.
Railway Network Plan in Sumatera Island.

there have been railway networks (existing tracks) in three provinces of North Sumatera, West Sumatera and South Sumatera with total length of track reaches 1,150 km of which the track gauge of 1,067 mm is 50,66%. However, the tracks in those three provinces are not interconnected each other. To create a good transportation system, the development of track on Trans Sumatera Railway must play the role to connect them to become an operation unit. With the selection of track gauge of 1,435 mm as the track gauge for Trans Sumatera Railway, in the encounter between track gauge of 1,435 mm and track gauge of 1,067 mm (existing track) there will be a break of gauge. So, there should be technological efforts to overcome the break of gauge problem. Break of gauge occurs a line of one gauge meets a line of different gauge, specifically a different track gauge. Trains and rolling stock cannot run through without some form of conversion between gauges and freight and passengers must otherwise be transshipped. A break of gauge adds delays, cost and inconvenience.

In order to overcome the occurrence of that break of gauge, many technologies can be implemented. The following are some examples that have been long applied in those countries and have been tested and successful.

1. Optimization

a. Track Gauge Changeover System (TGCS) First Generation

With the success of trial tests that have been performed intensively and the patent that has been obtained by Talgo, Talgo succeeded to produce trains designed using Variable Gauge Axle (VGA) or Gauge Adjuster Wheel (GAW) called Talgo RD which is almost the same as Talgo III but using standard gauge of 1,435 mm. To complete the equipment so that the operation can be done, Track Gauge Changer (TGC) or Track Gauge Adjustable Wheel (TGAW) is built in Port Bou (Girona) and on 19 May 1969 the train passing through it for test run was the first entered France. After the first test run in the beginning of June 1969 the Talgo III RD regular train operated commercially from Barcelona to Geneva via using the name Catalan Talgo. In 25 September 1994 the route of Catalan Talgo was shortened to be only Barcelona-Montpellier (since there has been operation of TGV from Montpellier to Geneva).

In 2009 in the borderline of Port Bou the installation of Track Gauge Changer had been used by two daytime trains (Talgo III RD) from

Barcelona to Montpellier and series six Talgo Mare Nostrum from Cartagena to Montpellier, and night train Barcelona-Paris and Barcelona-Milan-Zurich everyday. Track Gauge Changer in Port Bou and Irun are still well functioning, and until 2010 it has been passed through more than 88,514 train travels with no incidence. Track gauge changer is also installed at Maintenance Center (Maintenance Depot) Talgo in Barcelona and Las Matas in 1980.

b. Track Gauge Changeover System (TGCS) Second Generation

Track Gauge Changeover System second generation is an answer for the challenge of the high speed track in Spain built using standard gauge of 1,435 mm which is different from the existing track using Iberian gauge of 1,668 mm. Coincides with the completion of High Speed line from Madrid-Seville in 1992, Track Gauge Changer (TGC) was built in Cordoba to support the operation of Talgo 200 from Madrid to Malaga and to Algeciras. TGC second generation is an improvement and development of TGC technology first generation. Reengineering starts to be done in 1994-1997 by utilizing the technology for enhancing the security, comfort, speed operation as well as efficiency so that the cost is cheap. In the trial test of Track Changeover System operation that has been done, it is found that the operational time which is previously 20 minutes can be shortened to be nine minutes and finally can be shortened to be six and a half minutes. The train sequence whose wheel gauge will be changed runs on TGC at the speed of 10 km/hour.

c. Track Gauge Changeover System (TGCS) Third Generation

Observing the development of TGCS second generation and also the experiences during the operation, in fact technological improvement and refinement are needed. In addition, it is known that there are two new facts which can be used as inputs to create and accomplish TGCS third generation, namely; (1). The discovery of new technology TGCS developed by CAF, and (2). Possibility of wheel gauge changes on locomotive through TGCS so that when making changes on wheel gauge train series do not have to use hunting locomotive. The design of TGCS third generation has begun since 1999. In addition, Talgo also has developed Portable TGCS for changing wheel gauge of 1,435 mm to wheel gauge of 1,520 mm for Russia and of 1,524 mm for Finland.

d. The Development of Railway in China against Adjustable Wheel Gauge

China has started to develop high speed train since 2004 and until now this country has had high speed railway as long as about 22,000 km. It is programmed that in 2020 China will have 30,000 km and in 2030 it will reach 45,000 km. Today China is trying to work out High Speed Train whose wheel gauge system can widen or narrow (gauge adjustable wheel) in accordance with the track gauge passed through. The maximum speed programmed on the train which has gauge adjustable wheel is 400 km/hour, much faster than Shinkansen which has maximum speed of 320 km/hour. This is stated by Jia Limin, a professor from Jiaotong University of Beijing who is also the chief of innovative program of Chinese high speed train to China Daily newspaper on 25 September 2016. This high speed train has adjustable wheel gauge system which can operate on other countries' track gauge. This is also stated by Jia Limin who speaks in the 12th Technology Exhibition and Innovation Achievement in Beijing.

This Gauge Change Train is very possible for international travel and will save much time and give comfort to passengers that no need to interfere with their activities. It is the use of Gauge Change Train that can solve the problem of Break of gauge. This Gauge Change Train system can create integrated system track in Asia. China is designing the next generation of train which can carry passengers at the highest speed of 500 kilometers/hour (310 mph) and carry cargo at 250 km/hour, with gauge adjustable wheel in order to be suitable with track gauge used around the world. Jia Limin also states that China has started testing ultra-speed train having maximum speed of 600 km/hour. A prototype is still produced by CRRC Qiangdao Sifang, a subsidiary of China Railway Rolling Stock in the Province of Shandong. Considering the above description of operating and observing TGCS first generation, TGCS second generation, TGCS third generation and placing automatic track gauge changeover system in 33 locations and the development of gauge adjustable wheel in China, then if break of gauge happens, it can be overcome so that the train operation will not encounter obstacles.

2. Revitalization

a. High Speed Train Line (Mini Shinkansen)

The Gauge Change Train (GCT) or Free Gauge Train (FGT) is a Japanese railway project which started in 1994 to develop high speed train with Variabel Gauge Axles (VGA) to enable the train

operates in Shinkansen network with the standard gauge of 1,435 mm as well as at conventional network with narrow gauge of 1,067 mm. Two units of Electric Multiple Unit (EMU) trains each of which consists of three railway coaches and one unit of train comprising four railway coaches with the system of Gauge Change Train (GCT) have been developed for examination. The first generation train series operated from 1998 to 2006, the second generation operated from 2006 until 2014 and the third generation started examination in 2014. The system of Gauge Change Train (GCT) is planned to be introduced in Nagasaki Shinkansen in the opening scheduled to happen in 2022.

b. Gauge Change Train First Generation 1998-2006

The first Gauge Change Train (GCT) finished in October 1998. It is designed to operate at maximum speed more than 300 km/hour (185 mph) on Shinkansen route with standard gauge of 1,435 mm, and more than 130 km/hour (80 mph) on conventional track with narrow gauge of 1,067 mm and under the voltage of overhead catenary 25 kV AC (50/60 Hz), 20 kV AC (50/60 Hz), or 1,500 V DC.

c. Operationalization

After the preparation in Railway Technical Research Institute, 2012, in Kokubunji, Tokyo, the train is moved to track West JR in January 1999 for testing on Sanin route at high speed up to 100 km/hour (60 mph). The extension period of high speed endurance lasted from April 1999 until January 2001. In Tokyo, maximum speed 246 km/hour (153 mph) on standard gauge and operated traveling total distance as long as about 600,000 km (370,000 miles), with approximately 2,000 times of change on the wheel gauge (variable gauge axle). In November 2002, the train recorded maximum speed 130 km/hour (81 mph) on the conventional track Nippo in Kyushu with narrow gauge of 1,067 mm. From May to June 2003, this train was tested for the first time in Shikoku, in Yoson route between Sakaide Station and Matsuyama Station.

d. Gauge Change Train Second Generation (2006-2013)

It was initially scheduled to finish in 2004, the second train was sent in 2006, starting the trial test in JR Shikoku's Tadotsu Works. In March 2007 the train was sent from RTRI in Kokubunji to Kokura Works and exhibited to press in May 2007. The train was based on Shinkansen Seri E3, with maximum speed of 270 km/hour (170

mph) on Shinkansen route with standard gauge of 1,435 mm, operating under 25 kV AC (60 Hz), and 130 km/hour (80 mph) on the conventional track with narrow gauge of 1,067 mm operating under overhead Catenary 20 kV AC (60 Hz) or 1,500 V DC.

e. Operationalization

Starting from December 2007, trial test began on conventional track with narrow gauge of 1,067 mm between Kokura Works and Nishi-Kokura Station. Since June 2009, the train was going on trial test between Kyushu Shinkansen with standard gauge of 1,435 mm and conventional track with narrow gauge of 1,067 mm, operating at speed up to 270 km/hour (170 mph) on Shinkansen route with standard gauge of 1,435 mm. In 2011, the train was equipped with new lighter weight "E" bogies to enhance the stability and comfort of driving when passing through a curve with radius less than 600 m. This replaced the previous design of bogie D. Since August 2011 trial test lasted at the speed up to 130 km/hour (80 mph) on conventional track with narrow gauge of 1,067 mm in Yoson using the train based in Tadotsu. Subsequently the endurance test was done from December 2011 to September 2013 on Yoson route between Tadotsu and Matsuyama. During the trial test it had traveled around 70,000 km.

f. Gauge Change Train Third Generation (2014-now)

The third generation train, four trains were sent to Kumamoto Depot in Kyushu in the end of March 2014 with "three-mode" (standar gauge, gauge changing, narrow gauge). The measurement of endurance uses new facilities built near Shin-Yatsushiro Station starting from October 2014. The endurance test was scheduled to last until March 2017 and would have traveled total distance of 600,000 km. The test was stopped in December 2014 after going through operation of about 33,000 km.

g. Mini Shinkansen

Mini-Shinkansen is the name given to the concept of conversion from route/track with narrow gauge of 1,067 mm to route/track with standard gauge of 1,435 mm to serve the operation of shinkansen in Japan. It is not totally like high speed shinkansen railway, mini-shinkansen railway has maximum speed only 130 km/hour (80 mph) on the route/conventional track with narrow gauge of 1,067 mm. Two routes of mini-shinkansen have been developed: namely; Yamagata Shinkansen and Akita

Shinkansen. The concept of mini-shinkansen was first developed in the era of JNR, but not formally proposed until November 1987. Only after the establishment of East Japan Railway Company (JR East), mini Shinkansen was revealed. This concept concerns the implementation of Regauging on the existing conventional track with narrow gauge of 1,067 mm toward standard gauge of 1,435 mm and is connected to Shinkansen railway network. This will be able to operate at high speed (train of E6 seri has maximum speed of 320 km/hour) on Shinkansen track with standard gauge of 1,435 mm, and operates with narrow gauge on conventional track about 130 km/hour on mini-shinkansen track.

Considering the above description discussing about gauge change first generation and its operationalization, gauge change second generation and its operationalization and gauge change third generation and its operationalization as well as Mini-Shinkansen, Yamagata Shinkansen and Akita Shinkansen, thus from the existing track in Sumatera (West Sumatera and North Sumatera) there is no worry if in the future the tracks on Trans Sumatera Railway uses track gauge standard gauge of 1,435 mm.

The global trend for recent railway is the use of High Speed Rail (HSR) with track of standard gauge (1,435 mm). However, the benefit for transportation, if compared with the additional construction cost, is great and much more profitable because of higher speed, bigger axle pressure, bigger load capacity, better comfort and even in China the train speed with standard gauge of 1,435 mm has been able to reach 400 km/hour. Based on the analysis of track gauge alternatives to be used (**Table 1**), and the justification to choose one of the track gauges considered as better, along with the logical consequences of spoor width selection and the trend of using standard gauge, thus it is very realistic that the railway track in Sumatera, Indonesia uses standard gauge (1,435 mm).

IV. Conclusion

Data shows that of the railway tracks around the world almost 67,45 percent are the track with standard gauge of 1,435 mm and in general have become international standard. In order to fulfill the demand for future transportation, the development of Trans Sumatera Railway, especially new tracks, it is very appropriate to use standard gauge of 1,435 mm. In the connection of new tracks using standard gauge of 1,435 mm and the existing tracks using narrow gauge of

1,067 mm there will be a break of gauge due to different track gauge. To prevent the train operational service from obstacles the technology of track gauge adjuster must be implemented. For the smooth operation of connection between new track using standard gauge of 1,435 mm and the existing track in Provinces of South Sumatera, West Sumatera and North Sumatera using narrow gauge of 1,067 mm, it is necessary to build Track Gauge Adjuster construction which can facilitate the change from wheel gauge of 1,435 mm to wheel gauge of 1,067 mm and vice versa. To enhance the speed of train operation, subsequent regauging or change of spoor width from narrow gauge of 1,067 mm to standard gauge of 1,435 mm needs to be done in stages. The limitation of this research is that because the implementation of Trans Sumatera Railway development and the Government policy in its establishment still uses gauge of 1,067 mm, then the interviewees from the government giving inputs are very limited. The study of using track gauge adjuster construction in Indonesia in general and especially in Sumatera Island has not been done yet previously, then this research can be said to be a new research.

V. Recommendation

The construction of the Trans Sumatra Railroad is very precise using the width of the 1,435 mm separator as the Normal Track Gauge which is the same as the Railroad Track on Trans Kalimantan, Trans Sulawesi and Trans Papua which is 1,435 mm. As an input that the success of the Japanese Shinkansen to achieve higher speeds, begins with a gradual increase in speed on railroad tracks that

use a 1,435 mm track gauge. The old / existing train line can be upgraded to higher speeds by Regauging to the 1,435 mm track gauge or still being used for freight train services, while to connect with the Trans Sumatra line using a 1,435 mm track width a construction of a track gauge adjuster can facilitate wheel gauge changes from 1,435 mm to 1,067 mm wheel gauge. This study on the case of using narrow gauge and standard gauge will be interesting since the disadvantage of using narrow gauge is more prominent than using broad gauge. Therefore, in order to improve the result of this research in the future, further study on the comparative disadvantage of using both standard spoor widths.

Acknowledgments

The authors gratefully acknowledge the support and comments provided by Directorate General of Railways, the Ministry of Transportation, that the observers are trainee resource persons. The authors also deliver gratitude to Trisakti Institute of Transportation and Logistics (ITL) that has organized a national seminar in Jakarta so that the authors get some inputs about railway studies, and thank to the provided assistance to complete the documents for this journal.

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Table 1.
Recapitulated Usage Comparison of Track between Narrow Gauge and Standard Gauge

No.	Description	Track with Narrow Gauge (1,067 mm)	Track with Standard Gauge (1,435 mm)	Advantages of Using Standard Gauge
1.	Axle pressure	20 Ton	30 Ton	Big load capacity
2.	Minimum Radius	100 m	250 m	For speed of 10 km/hour
3.	Maximum Speed	120 km/hour	More than 200 km/hour	The global trend is high speed
4.	Free Space	Normal	Insignificant difference	The difference is only 20 cm
5.	Rolling Stock/Facilities	Small, special order	Big, many choices	Many factories for 1,435 mm
6.	Stability, Comfort	Less stable	Stable and comfortable	Due to wide gauge
7.	Construction Cost	Cheaper	Normal	Very reasonable
8.	Load Capacity	Small	Big	Rolling stock is big and fast
9.	World Usage	10,49 percent	67,45 percent	The rests are Broad Gauge
10.	High Speed Rail (HSR)	None	All HSR	Global trend

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