DYNAMIC BEHAVIOUR OF HIGH SPEED TRAIN: PERFORMANCES AND COMPARISION BETWEEN ETR1000, ETR500, ICE3 and TGV

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Abstract:

The goal of this Thesis is to identify “DYNAMIC BEHAVIOR OF HIGH SPEED RAIL and Performance in the FIRENZE SANTA MARIA NOVELLA to BOLOGNA CENTRALE HIGH SPEED LINE” practices starting from the Operational Performances, Energy Consumption, 10% of Weight Reduction of all trains and only we done a Future line mark ETR1000 High Speed Train with maximum speed is 330km/h and 360 km/h.

Practices of high speed rail are ETR1000 and comparing with three different type high speed Trains ETR500, ICE3 and TGV-THALYS.

Speed is 300 km/h and Electric system is 25 kV 50 Hz is used for SANTA MARIA NOVELLA to BOLOGNA CENTRALE LINE high-speed rail systems currently in operation line.

New generation high speed trains are designed to have better performances, retain the safety of the rolling stock at higher speed and guarantee the passengers comfort. Design features are verified during the homologation and the commissioning of the train.

The opportunity to perform some measurements on the train allows to define the characteristics of the rolling stock and to assess the reliability of design procedures and numerical codes used to predict the train performances. Weight reduction has done by following technical characteristics of all trains are ETR1000, ETR500, ICE3 and TGV-THALYS.

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The topic was "DYNAMIC BEHAVIOUR OF HIGH SPEED TRAIN PERFORMANCE AND COMPARISION BETWEENETR1000 AND ETR500, ICE3 Velaro E and TGV-THALYS". He is impressed about my work to complete thesis at that time. Really thank for that giving chance to discuss my thesis.

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CHAPTER 1

SUMMARY OF THESIS

SUMMARY:

In this summary, we_are discussing chapter wise for know the Dynamic behaviour of high speed passenger mainly on performance of ETR1000 high speed passenger train and comparing with ETR500, ICE 3 Velaro E and TGV-THALYS.

In chapter 2 we introduce the high speed passenger train system developed in Europe and the trains ETR1000, ETR500, ICE 3 Velaro E and SNFC TGV-THALYS.

In chapter 3, we are given objectives of high speed passenger train and specific goals of this thesis.

In chapter 4, we describe the route of Firenze Santa Maria Novella to Bologna Centrale. On this track are compared the performances of four different type of high speed trains.

In chapter 5, we list data of high speed passenger train especially maximum speed, maximum weight, tractive effort etc...

In chapter 6, case study of Firenze Santa Maria Novella to Bologna Centrale line specific characters are relation between speed and distance, maximum gradient etc...

In chapter 7, we done a process of behaviour of ETR1000 high speed passenger train with maximum speed of 300km/h and made a two process a) without limit speed and b) with limit speed for know the dynamic behaviour and performance of train speed comparing all trains in graph to know the performance.

In chapter 8, first we analyse the weight of train (with the Catalogue, Siemens and Bombardier Company) bogies weight, total weight & car weight of high speed trains and comparing to know weight is increasing or decreasing then we decide to reduce the weight.

In chapter 9, weight reduction process by using chapter 8 process mainly we reduce high speed passenger train and comparing all trains in graph to know the performance.

In chapter 10, only we done a Future line mark of ETR1000 High Speed Train with maximum speed is 330km/h and 360 km/h. It means analysis on maximum speed 330km/h and 360km/h in the line of Firenze Santa Maria Novella to Bologna Centrale.

In chapter 11, Conclusion of dynamic behaviour and performance of ETR1000 high speed passenger train and comparing other trains are ETR500, ICE 3 Velaro E & TGV-THALYS.

CHAPTER 2

INTRODUCTION

HIGH SPEED PASSENGER TRAIN:

High speed rail is emerging in Europe as an increasingly popular and efficient means of transport. The first high-speed rail lines in Europe, built in the 1980s and 1990s, improved travel times on intra-national corridors.

Since then, several countries have built extensive high-speed networks, and there are now several cross-border high-speed rail links. Railway operators frequently run international service, good performance and tracks are continuously being built and upgraded to international standards on the emerging European high-speed rail network.

Figure 1: ETR1000 High Speed Passenger Train (source 1 in reference pg 92)

In 2007, a consortium of European railway operators, Rail team, emerged to co-ordinate and boost cross-border high-speed rail travel. Developing a Trans-European high-speed rail network is a stated goal of the European Union, and most cross-border railway lines receive EU funding.

Several countries — Italy, Germany, France, Spain, Austria, Sweden, Belgium, the Netherlands, Russia and the United Kingdom — are connected to a cross-border high-speed railway network.

More are expected to be connected in the coming years as Europe invests heavily in tunnels, bridges and other infrastructure and development projects across the continent, many of which are under construction now. Alstom was the first manufacturer to design and deliver a high speed train or HS-Train, which ended up in service with TGV in France. Currently, there are a number of high-level manufacturers designing and building HSR in Europe, with criss-crossed alliances and partnerships, including Canadian company Bombardier, Alstom itself, the Spanish Talgo, Italian company Hitachi rail and the German Siemens.

In addition, identification of areas of improvement in production and marketing is important to optimize operational performance and productivity. National governments decide on the development of HSR systems basing on the expected future demand for high-speed travel and the social benefits for the country. Long-term performance forecasts for high-speed rail are a basic input for the decision-making process, and performance (source 2 in reference pg 92)

We analyse the Firenze Santa Maria Novella to Bologna Centrale High Speed Line about performance of ETR 1000 high speed passenger train.

The goal of this Thesis is to identify "DYNAMIC BEHAVIOR OF HIGH SPEED RAIL and Performance in the FIRENZE SANTA MARIA NOVELLA to BOLOGNA CENTRALE LINE" practices starting from the Operational Performances, Energy Consumption, 10% of Weight Reduction and only we done a Future line mark of ETR1000 High Speed Train with maximum speed is 330km/h and 360 km/h rail systems.

Practices of high speed rail are ETR1000 and comparing with three different type high speed Trains ETR500, ICE3 and TGV-THALYS.

Speed is 300 km/h and Electric system is 25 kV 50 Hz is used for SANTA MARIA NOVELLA to BOLOGNA CENTRALE HIGH SPEED LINE.

CHAPTER 3

OBJECTIVE OF HIGH SPEED PASSENGER TRAINS

Main objectives of high speed Passenger trains

New generation high speed trains are designed to have better performances, retain the safety of the rolling stock at higher speed and guarantee the passengers comfort. Design features are verified during the homologation and the commissioning of the train. The opportunity to perform some measurements on the train allows to define the characteristics of the rolling stock and to assess the reliability of design procedures and numerical codes used to predict the train performances.

Following the Technical Specification of Interoperability:

- Improving the speed for ETR 1000 train
- Optimized performance characteristics
- High Energy savings due to available passengers
- Quality in performance of train
- Safety : the safety of the rolling stock at higher speed
- Comfort : planning and spacing for passengers
- Reliability of designed procedure

THESIS GOALS OF PERFORMANCE OF TRAIN:

- Speed, Time Consuming, Commercial Speed and Energy Consumption
- Weight reduction has implemented for mainly getting to know performance of train, energy savings.
- Technical data is availability of design
- Time : Reasonable time is required to reach origin to destination
  Frequency and regularity of trains are required for passengers to reach destination point.
- Future operations has done in two scenarios is maximum speed line are 330 km/h and Italy design speed is 360 km/h

CHAPTER 4

DESCRIPTION OF

FIRENZE SANTA MARIA NOVELLA TO BOLOGANA CENTRALE

Description of high speed line from Firenze Santa Maria Novella to Bologna Centrale:

The Florence – Bologna high-speed railway is a link in the Italian high-speed rail network. It is part of Corridor 1 of the European Union's Trans-European high speed rail network, which connects Berlin and Palermo. Full commercial operations commenced on 5 December 2009.

High speed passenger trains take currently 37 minutes over the route compared to about 59 minutes previously. The line will extended for approx. 96.484 km, connected Bologna and Florence stations.

Its southern end is at Firenze Santa Maria Novella railway station and it connects with the Florence–Rome high-speed line. It is used by high speed passenger trains, while some goods trains will continue to use the old Bologna–Florence railway, completed in 1934 and known as the Direttissima.

The line includes 73.8 km of tunnels, 3.6 km on embankment or in cutting and 1.1 km on viaduct.

The Tunnels in line from Firenze Santa Maria Novella to Bologna Centrale are

i. Pianoro 10,841 m
ii. Sadurano 3,855 m
iii. Monte Bibele 9,243 m
iv. Raticosa 10,450 m
v. Scheggianico3,558 m
vi. Firenzuola 15,285 m
vii. Borgo Rinzelli 717 m
viii. Morticine 654 m
ix. Vaglia 18,713 m

Maximum rock coverage over tunnels is about 600 to 700 m. All tunnels are double track. Each tunnel has an intermediate access from the surface about every 5 km, except the Vaglia tunnel, which instead has a parallel service tunnel for about half of its length.

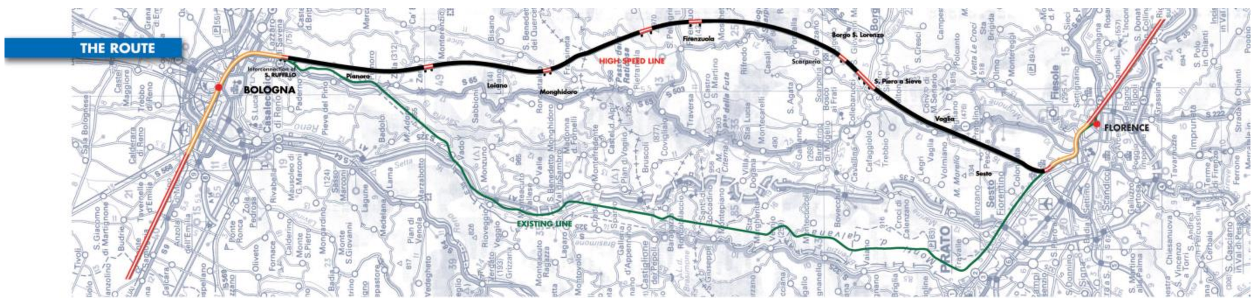


Figure 2: Shown a Route of Firenze Santa Maria Novella to Bologna Centrale (source 3 in reference pg 92)

The construction of the line, including electrification, was completed in 2008 and testing of the line commenced in December 2008. The line was handed over to the rail network on 30 June 2009. The first commercial service occurred on 4 December 2009 and it was officially opened next day.

The line was estimated to cost €1 billion (1991 values in lire converted to euro), but ended up costing €5.2 billion (€67million per km) (source 4 in reference pg 92)

CHAPTER 5

TYPES AND TECHNICAL CHARACTERISTICS OF TRAINS

HIGH SPEED PASSENGER TRAINS:

High-speed rail is a type of rail transport that operates significantly faster than traditional rail traffic, using an integrated system of specialized rolling stock and dedicated tracks. While there is no single standard that applies worldwide, new lines in excess of 250 kilometres per hour (160 miles per hour) and existing lines in excess of 200 kilometres per hour (120miles per hour) are widely considered to be high-speed, with some extending the definition to include lower speeds in areas for which these speeds still represent significant improvements.

Defines high-speed rail in terms of:

1. **Operating conditions:** Rolling stock must be designed alongside its infrastructure for complete compatibility, safety and quality of service.

2. **Minimum Speed Limit:** Minimum speed of 250 km/h (155 mph) on lines specially built for high speed and of about 200 km/h (124 mph) on existing lines which have been specially upgraded. This must apply to at least one section of the line. Rolling stock must be able to reach a speed of at least 200 km/h (124 mph) to be considered high speed.

3**. Infrastructure:** track built specially for high-speed travel or specially upgraded for high-speed travel.

The International Union of Railways (UIC) identifies three categories of high-speed rail:

Category I – New tracks specially constructed for high speeds, allowing a maximum running speed of at least 250 km/h (155 mph).

Category II – Existing tracks specially upgraded for high speeds, allowing a maximum running speed of at least 200 km/h (124 mph).

Category III – Existing tracks specially upgraded for high speeds, allowing a maximum running speed of at least200 km/h (124 mph), but with some sections having a lower allowable speed (for example due to topographic constraints, or passage through urban areas).
(Source 5 in reference pg 92)

Types of trains:

I. Distributed power: with the technical equipment under the car bodies.
II. Two locomotive and trailers
III. Concentrated power: with one or two end power heads.

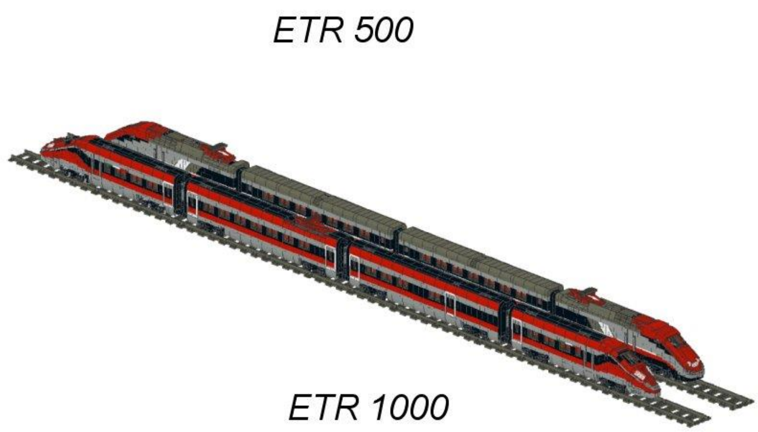


Figure 3: High Speed ETR1000 AND ETR500 Trains (source 6 in reference pg 92)

FOR THESIS WE CONSIDERED HIGH SPEED PASSENGER TRAINS ARE:

5.1 FRECCIAROSSA 1000:

The Frecciarossa 1000, also known as the ETR 1000 (Elettro Treno Rapido, Trenitalia classification) is a high-speed train operated by Italian state railway operator Trenitalia. It was co-developed as a joint venture between Italian rail manufacturer Ansaldo Breda (now Hitachi Rail Italy) and multinational conglomerate Bombardier Transportation. Both design and production works were divided between the two partner companies.

In 2010, the ETR 1000 was selected and a total of 50 train sets were ordered to meet Trenitalia's needs. Upon the public unveiling of the first example of the type, it was hailed as being the fastest train to reach series production in Europe at that time.

Figure 4: ETR1000 High Speed Passenger Train **(Source 1 in reference pg 92)**

During the mid 2000s, Italian state railway operator Ferrovie dello Stato became increasingly interested in the acquisition of a new very-high-speed train for its Eurostar Alta Velocità Frecciarossa (Eurostar high speed Red Arrow) services along the Turin-Milan-Florence-Rome-Naples corridor. Having become aware of this interest, Italian rail manufacturer Ansaldo Breda and multinational conglomerate Bombardier Transportation decided to partner up to produce a suitable train in 2008. It was decided to centralize design work by the joint venture at a single location, working out of an office at Bombardier's manufacturing plant at Hennigsdorf.

The emergent design was a 200 meter-long eight car non-articulated single decker train with distributed traction, capable of reaching a maximum speed of 350 km/h (217 mph); it was heavily based on elements of Bombardier's Zefiro and Ansaldo Breda's V250 existing train designs. According to rail industry publication Rail Engineer, Bombardier personnel were responsible for conducting the concept and detailed design phases of development, as well as for the provision of propulsion equipment and bogies, homologation efforts, testing, and the commissioning of the first five trains. Meanwhile, Ansaldo Breda developed the train's industrial design, including body, interior, signalling and other systems, in addition to performing the final assembly and commissioning of series production trains. Both firms were involved in detail design and engineering activity.

Italian vehicle manufacturer and design company Gruppo Bertone was involved in the designing of the train's aesthetics and appearance. It was instructed to produce a style that accentuated its elegance and speed, but would also conform to various international railway standards, such as driver visibility, crash protection, and headlight functionality. Bertone's design was reviewed by the team and subject to various tests, including the use of a wind tunnel, which proved it to be produce compliant drag coefficients and crosswind stability levels. The train's design includes an active suspension system.

Having been deemed suitable for presentation, the vehicle design, which had been formally designated as the Zefiro 300, was submitted by the joint venture as a response to Ferrovie dello Stato's tender for 50 new high-speed train sets. Initial specifications were for a train meeting European high-speed technical standards, with a design commercial speed of 360 km/h (220 mph), initially operated at 300 km/h (190 mph), and to be tested to 400 km/h (250 mph).Other requirements included the train being suitable for a condition-based maintenance program, while it was capable of being operated across seven different European countries, specifically the railway systems of Italy, France, Germany, Austria, Belgium, Netherlands, Spain and Switzerland.

The maximum speed specified by the tender exceeded that of the initial design, thus the design team was reassembled by Ansaldo Breda's Pistoia facility for a period of six months to revise the design to comply with the requirements outlaid. Reportedly, the new top speed required a detailed re-examination of the design and in some cases the redesign, to be performed for various elements of the train, including the bogies, power and control systems and pantograph.

While the train was to only fit with ERTMS Level 2 and the legacy Italian signalling system, passive provisions also had to be found for a number of other signalling systems that had been listed in the requirement. The introduction of the ETRs 1000 shall enable Trenitalia to redeploy its existing ETR 500 high-speed trains onto other routes, such as Milan – Venice and the Adriatic coast. Early on, it was also declared by FS president Marcello Messori noted that the ETR 1000 had enabled Trenitalia to compete in the international high-speed market, and that it had been approved for operation in France, Germany, Spain, Austria, Switzerland, the Netherlands, and Belgium.

On 26 November 2015, it was reported that one of the ETR 1000 eight-car sets reached 389 km/h during testing; however, under normal initial conditions, the trains will be limited to 300 km/h as this remains the maximum permitted speed on the Italian high-speed network.

On 26 February 2016, an ETR 1000 reportedly attained a peak speed of 393.8 km/h while traversing the Torino-Milano high speed line (source 7 in reference pg 92)

5.2 FRECCIAROSSA 500

FRECCIAROSSA 500 known as ETR 500 (ElettroTreno Rapido 500) is a family of Italian high-speed trains introduced in 1993. Designed under the aegis of the Ferrovie dello Stato (FS), it is now operated by Trenitalia on RFI tracks.

The opening of the Direttissima line, connecting Florence with Rome, in stages between 1978 and 1991 was the first high speed line in Europe. Then, in the 1990s, FS unveiled plans to build a whole new high speed network. As the larger part of the network would be suited for speeds of 300 km/h (186 mph), new, non-tilting trains had to be designed as the tilting equipment used in the ETR 450, 460 and 480 Pendolino series was not suited for speeds of over 250 km/h (155 mph).

Figure 5: ETR500 High Speed Passenger Train (source 8 in reference pg 92)

The new train was to be built by the TREVI (TREno Veloce Italiano, "Italian Fast Train") formed by Breda Costuzioni Ferroviarie, FIAT Ferroviaria, Tecnomasio and FiremaTrasporti. With the new high-speed lines finally in construction, FS chose to electrify the lines at 25 kV 50 Hz AC instead of 3 kV DC as used on the classic network. This allows the trains to drive at their top speed of 300 km/h (186 mph), as 3 kV is technically limited to 250 km/h (155 mph) operation.

As the first generation trains cannot operate off 25 kV AC, new trains had to be ordered. As the new trains can run both off 25 kV AC and 3 kV DC, they were designated P for poli-tension (multi-current).

In 2008, Trenitalia introduced new brand names for its Eurostar Italia Alta Velocità high-speed trains that categorise them according to top speed. The new brand name for trains with top speeds in the 300–350 km/h range is Frecciarossa (meaning Red Arrow).The ETR 500 and the new ETR 1000 are currently the only trains qualifying as Frecciarossa. The trains receive a new livery with a red stripe and the brand name on the power cars. (source 9 in reference pg 92)

5.3 ICE3 Velaro E

The Velaro for Spain (Velaro E) train is based on the advanced ICE 3 train of German Rail (DB AG), which is currently the world's fastest train in commercial service. The trainset develops 8,800 kW traction power for a maximum operating speed of 350 km/h.

It offers the highest degree of comfort and, with its four onboard galleys, high quality catering for 405 Passengers in three classes. Comfort and safety are guaranteed by the proven running gear technology from Siemens, while entertainment is provided by the audio and video programs. The advanced European ETCS Level 2 signaling system based on the GSM-R standard, as well as the proven LZB – both systems from Siemens –protect train operations.

The high-performance Velaro family is operating in four climatic zones, and also demonstrating its adaptability to different track gauges. The Spanish and Chinese versions are based on Europe's 1,435-mm standard gauge, while Velaro Russia is built for that country's 1,520-mm broad gauge.

The Velaro E is a multiple-unit trainset in which the traction and all technical modules are distributed under floor over the length of the train. This means that the full length above floor of the train is available to the passengers, offering 20 % more room than conventional trains of the same train length.

The ICE 3 of German Rail and the Velaro E are the first European high speed EMU type Trainsets that are proving their value in passenger service.

Other characteristics are:

Improved leverage of the adhesion coefficient during acceleration because 50% of the axles are driven and Capability to start up on sections with steep gradients up to 40%. Due to the evenly distributed weight across the entire trainset, the load for the individual wheelset is reduced. This goes easy on the track and reduces the maintenance requirements on the running gear. The load per wheelset is significantly lower than the international standard of 17 metric tons.

Figure 6: ICE3 VELARO E High Speed Passenger Train (source 10 in reference pg 92)

The train length of 200 m has been perfectly chosen in view of the requirements of the Technical Specification of Interoperability (TSI). It means that the train can run in double traction – with a total length of 400 m.

To achieve the huge traction performance, the transformer rating has been increased by 10 % over the ICE 3 of DB AG.

The bogies that are known from the ICE 3 of German Rail contribute to the exemplary lateral guidance performance of the Velaro E. They also maximize the stability for an excellent running comfort. Even more important than a rapid acceleration is a rapid deceleration. On the Velaro E, the electric brake allows automatic switchover and braking in regenerative and rheostatic mode. Braking in regenerative mode is preferred in routine service. Only when the network is no longer able to absorb the electric braking energy of the traction motors will the rheostatic brake be used. (Source 11 in reference pg 92)

5.4 SNFC TGV-THALYS (PBKA) :

Thalys (French: talis) is a French-Belgian high-speed train operator originally built around the LGV Nord high-speed line between Paris and Brussels. This track is shared with Eurostar trains that go from Paris, Brussels or Amsterdam to London via Lille and the Channel Tunnel and with French domestic TGV trains.

The Thalys PBKA is a high-speed train derived from the French TGV. It operates the Thalys service between Paris, Brussels, Cologne (German: Köln) and Amsterdam, forming the abbreviation PBKA.

Unlike Thalys PBA sets, the PBKA sets were built exclusively for the Thalys service. Their motor cars are technologically similar to those of TGV Duplex sets, but the trains do not feature bi-level carriages. They have eight carriages and are 200 m (656 ft) long, weighing a total of 385 tonnes. They have a capacity of 377 seats.

All of the trains are quadri-current, capable of operating under 25 kV 50 Hz AC (LGVs and a part of the French, lignes classiques), 15 kV 16.7 Hz AC (Germany), 3 kV DC (Belgium) and 1.5 kV DC (the Netherlands and the remainder of the French lignesclassiques).

Their top speed in service is 300 km/h (186 mph) under 25 kV, with two power cars supplying 8,800 kW. When operating under 15 kV AC or 1,500 V DC, the power output drops to 3,680 kW, Insufficient to reach 300 km/h in commercial use. Although their power-to-weight ratio allows a 250 km/h operation under 15 kV AC,further constraints resulted in imposing a limit of 200 kM/h on these trains in Germany. (Source 13 in reference pg 93)

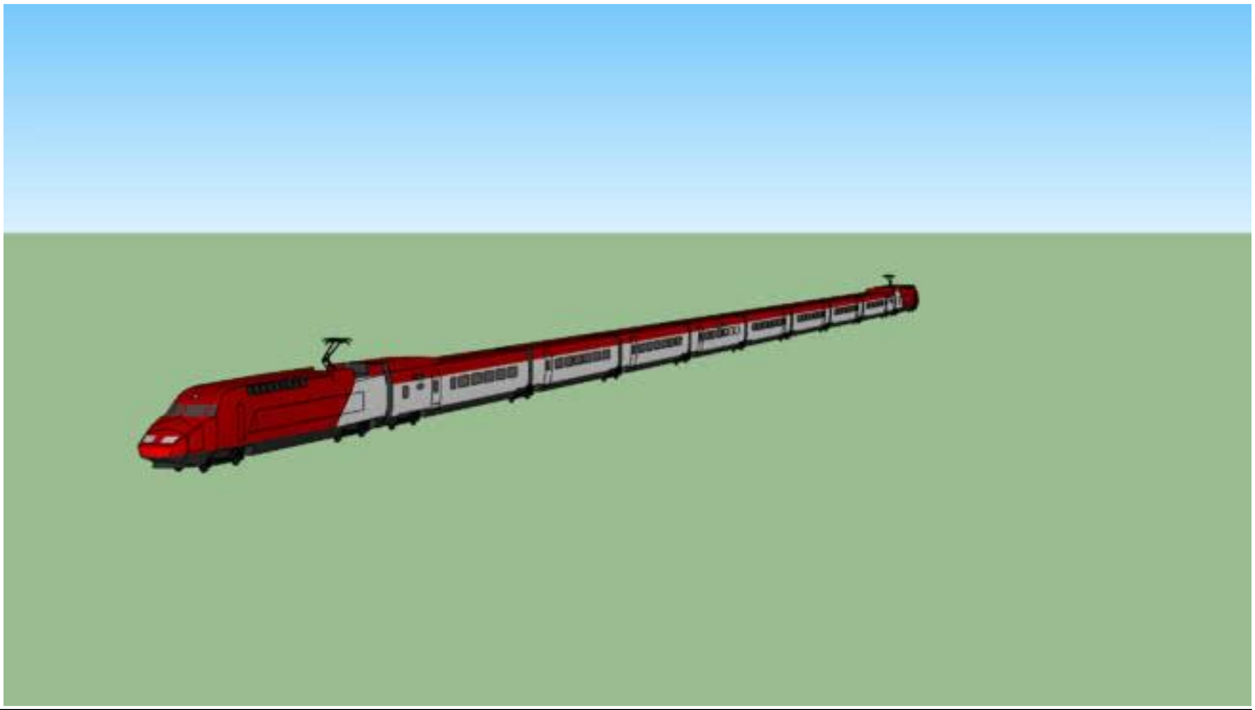


Figure 7: SNFC TGV-THALYS (PBKA) High Speed Passenger Train
(Source 12 in reference pg 93)

Mainly focus on performance of TGV-THALYS HIGH SPEED PASSENGER TRAIN:

Economics are Reduction of the number of bogies, Reduction of weight and Reduction of energy consumption. Comfort Noise sources are far from the passenger Compartments Structure-borne noise transmission is very low Safety Excellent technical characteristics.

CHARACTERISTICS OF HIGH SPEED TRAINS:

Table 1 as shown given data of High Speed Trains mainly on: companies, formation cars and operators of High Speed Trains

TABLE 1: TECHNICAL CHARACTERISTICS OF TRAINS

TRAINSET NAME	ETR 1000	ETR 500	ICE3 VELARO E	SNFC TGV-THALYS
MANUFACTURER	ANSALDO BREDA / HITACHI RAIL	TREVI CONSORTIU M	SIEMENS	ALSTOM
BUILT AT	PISTOIA		DEUTSCHE BAHN	
COUNTRY	ITALY	ITALY	GERMANY	FRANCE
CONSTRUCTED	2010-PRESENT	1988-1998	2000-PRESENT	1970-PRESENT
ENTERED SERVICE	2015	1990-PRESENT	PRESENT	1998-PRESENT
NUMBER BUILT	50	61	50	17
FORMATION	8CARS DISTRIBUT ED	2LOCOMOTIV E+ 11TRAILOR	8CARS DISTRIBUT ED POWER	10CARS CONCENTRAT ED
CAPACITY	457 SEATS	574 SEATS	405 SEATS	377 SEATS
OPERATOR	TRENI ITALIA	TRENI ITALIA	DEUTSCHE BAHN	SNCF

CHARACTERISTICS OF HIGH SPEED TRAINS:

Table 2 given mainly on technical characteristics and components of high speed trains especially ETR1000, ETR500, ICE 3 Velaro E and TGV- THALYS trains.

TABLE 2: TECHNICAL SPECIFICATION OF HIGH SPEED TRAINS:

TRAIN NAME	ETR 1000	ETR 500	ICE 3 VELARO E	SNFC TGV-THALYS
SPECIFICATION				
CAR BODY CONSTRUCTION	ALUMINIUM ALLOY	ALUMINIUM ALLOY	ALUMINIUM ALLOY	ALUMINUM WITH CARBON COMPOSITE IN ARTICULATION SECTION
TRAIN LENGTH	202 m	204.6 mm	200.32 mm	200
WIDTH	2,924 mm	3,020 mm	2,95 mm	2,81 mm
HEIGHT	4,080 mm	4,000 mm	3,89 mm	
FLOOR HEIGHT	1,240 mm	1,240 mm	1,240 mm	
DOORS	28			
WHEEL DIAMETER	920 mm	1040 mm	920 mm	
MAXIMUM SPEED	300km/h (operating) 360km/h (operating future) 400km/h (design)	300 km/h (operating)	300 km/h (operating) 320 km/h (operating) 330km/h (design)	300 km/h (operating)
TAIL LOAD	454 ton	598 ton	439 ton	383 ton
HEAD LOAD	490 ton	664 ton	474 ton	428 ton
AXLE LOAD	Max 17 ton	17 ton	17 ton	17 ton
TRACTION SYSTEM	Water Cooled IGBT converters Asynchronous AC traction motors			
POWER OUTPUT	9,800 kW	8,800 kW	8,800 kW	5,500 kW
TRACTIVE EFFORT	370kN	340kN	300kN	220kN

ACCELERATION	0.7 m/s2			
DECELERATION	1.2 m/s2			
ELECTRIC SYSTEM	25 kV 50Hz AC 15 kV 16.7Hz AC 3 kV DC 1.5 kV DC overhead catenary	25 kV 50Hz 3 kV CC 1.5 kV CC	25 kV 50Hz	25 kV 50Hz
CURRENT COLLECTION METHOD	PANTOGRAPH	PANTOGRAPH	PANTOGRAPH	PANTOGRAPH
BRAKING SYSTEM	Regenerative system Dynamic system Electro Pneumatic	Pneumatic Rheostatic	Regenerative system Pneumatic Rheostatic	Pneumatic
SAFETY SYSTEM	ERTMS ETCS	ERTMS ETCS	SIFA, PZB90, LZB	
TRACK GAUGE	1,435 mm (standard)	1,435 mm (standard)	1,435 mm (standard)	1,435 mm (standard)

CHAPTER 6

CASE STUDY OF
FIRENZE SANTA MARIA NOVELLA TO BOLOGANA CENTRALE LINE

FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE HIGH SPEED LINE :

By using characteristics of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line

Figure 8, as shows a route of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line

- The distance is around 96.484 km from Firenze Santa Maria Novella to Bologna Centrale.
- Max speed limit is 300 km/h.
- Electric system is 25 kV 50 Hz
- Actual travel time is around 35 min
- Max gradient is +15.00 (1/1000)
- Tunnel distance is around 73.5 km.

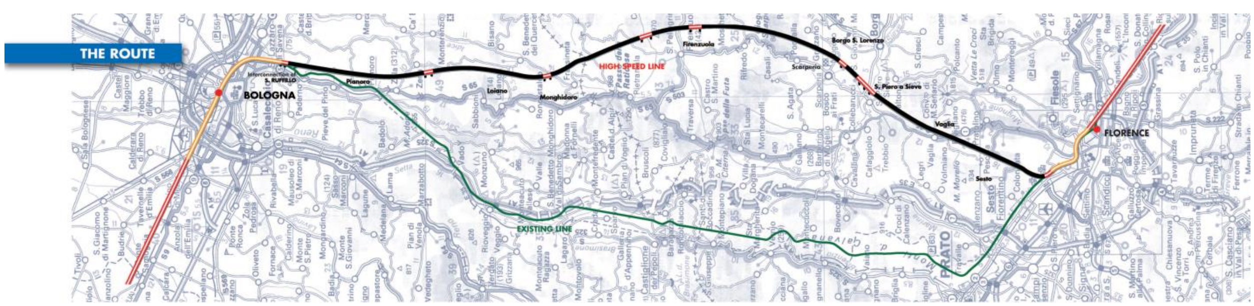


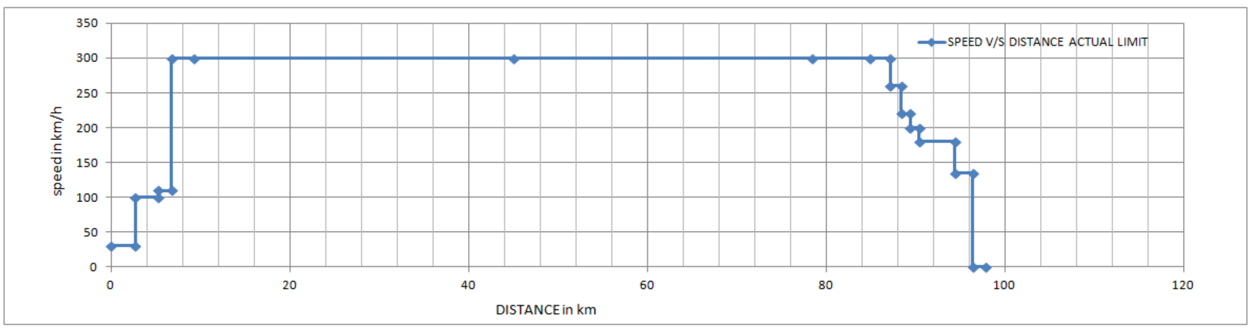
Figure 8: Route of Firenze Santa Maria Novella to Bologna Centrale High Speed Line (source 3 in reference pg 92)

CHARACTERISTICS OF FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE

RELATION OF SPEED V/S DISTANCE ACTUAL LIMIT:

We analysing the first step, 20km/h speed was assumed around distance 3km. But actual speed limit is 30km/h in distance 3km to 5km. In this graph we shown actual limit speed when we analysing we know the differences in graph.

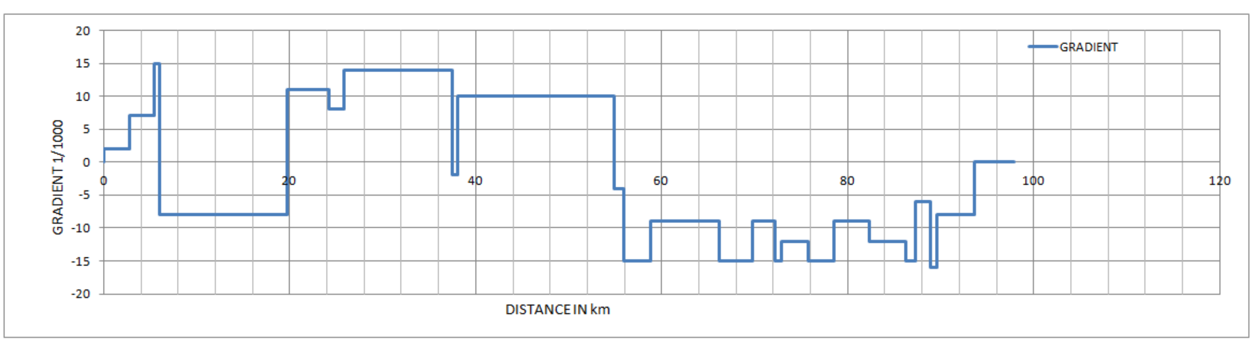
We are shown graph 1 in below, relation between speed and distance with actual speed limit is 300km/h from FIRENZE Firenze Santa Maria Novella to Bologna Centrale high speed line with distance is 96.484km.



Graph 1: Maximum Speed limit is 300 km/h, route from Firenze Santa Maria Novella to Bologna Centrale. (source 14 in reference pg 93)

GRADIENT OF FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE :

We are shown graph 2 in below, relation between gradient and distance with actual speed limit is 300km/h from Firenze Santa Maria Novella to Bologna Centrale High Speed Line and also maximum gradient is +15.00(1/1000) with distance is 96.484km



Graph 2: Surface of line Firenze Santa Maria Novella to Bologna Centrale is shown in above figure. (Source 15 in reference pg 93)

CHAPTER 7

DYNAMIC BEHAVIOUR & PERFORMANCE OF ETR1000 HIGH SPEED TRAIN

7.1 METHODOLOGY:

Main aim of objectives of:

Theoretical Methodology for this operation, we find the mainly on Performance of train and Energy Consumption.

As a theoretically, we calculated some physical methods to derive Distance, Time, Acceleration and Energy consumption of both engine and wheel.

Theoretical equation is considered for this operation:

- The motion consists of three phases: starting, constant and braking.
- The commercial speed is obtained as the ratio between the distance travelled and the time employed to follow it.
- Acceleration (a) and assumed constant deceleration (d) are Valid for the following formulas.

General equation of motion=>

Force = mass * acceleration

- ✓ $F = M\,a$ [N]

Exact resolution (continuous function) =>

dt = mass * delta speed / Traction force-Resistance force

- ✓ $dt = \frac{M\,dv}{T(v) - R(v)}$ [s]

Finite elements approximate resolution:

(Discrete function) =>

Δt = mass * speed / Traction force-Resistance force

- ✓ $\Delta t = \frac{M \, \Delta v}{T(vm) - R(vm)}$ [s]

Starting:

- ✓ $Sa = \frac{(Vmax)2}{2*a}$ [m]
- ✓ $ta = \frac{Vmax}{a}$ [s]

Braking:

- ✓ $Sf = \frac{Vmax2}{2*d}$ [m]
- ✓ $tf = \frac{Vmax}{d}$ [s]

Units = (meters)

Commercial speed:

Vc = Distance of origin to destination / Total travelling time of origin to destination

- ✓ $Vc = \frac{L}{ta+tr+tf+ts}$ [m/s] or [km/h]

Power:

Power = Tractive Force * Speed

- ✓ $P = T * V$ [kW] or [W]

Energy input:

Energy input or engine = power * time

- ✓ $E\ input = P * t$ [kW-h] or [W-h]

Energy output:

Energy output or wheel = energy input * efficiency

- ✓ $E\ output = E\ input * \eta$ [kW-h] or [W-h]

Ratio:

Normal Resistance (ETR 500) = mass of ETR 500 * Resistance (ETR 1000) / mass of ETR 1000

- ✓ $R\ (ETR500) = \frac{M\ (ETR500) * R\ (ETR1000)}{M\ (ETR1000)}$ [N] or [kN]

Resistance with Slope:

Resistance with Slope = actual resistance of train+ ((gradient * weight of train) (included tunnel))

- ✓ $R\ (Slope) = R + (i * W)$ [N] or [kN]

7.2 ETR1000 (ZEFIRO) High Speed Passenger Train (detailing) components:

We showing data of ETR1000 High Speed Passenger Train mainly on

Components of ETR1000 high speed passenger train:

- Empty weight(Tare load) = 454 Ton
- With passenger weight (100%) = 490 Ton
- Operated maximum speed = 300 km/h
- Maximum power = 9800 kW
- Electric system = 25 kV 50 Hz
- Formation = 8 cars (Distributed power)
- Capacity = 457 seats
- Efficiency = 90 %

Figure 9: ETR1000 (ZEFIRO) High Speed Passenger Train (source 16 in reference pg 93)

7.3 PERFORMANCE OF ETR1000 HIGH SPEED TRAIN

Some analyse are done by using characteristics of ETR 1000 high speed passenger trains.

7.3.1 Tractive effort and Resistance:

A. Tractive effort :

The force which a locomotive can exert when pulling a train is called its tractive effort, and depends on various factors. For electric locomotives, which obtain their power by drawing current from an external supply, the most important is

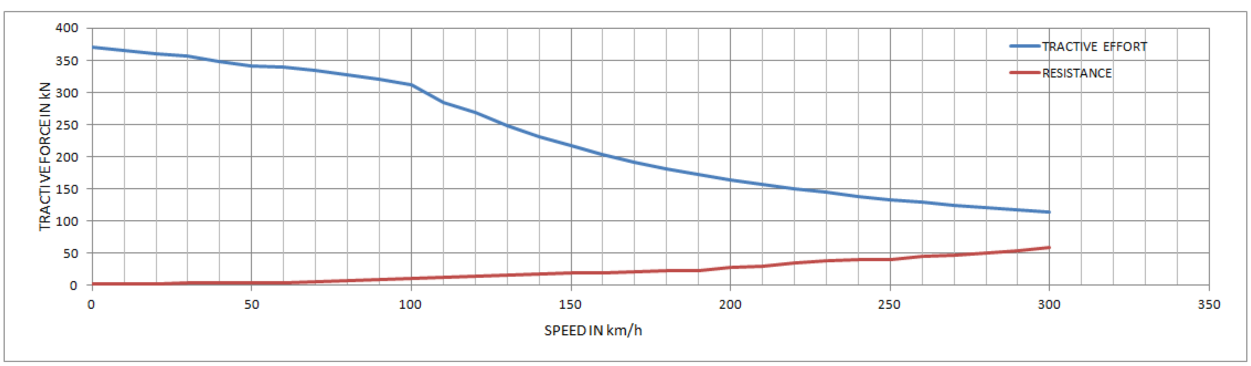
- Weight: The adhesion between the driving wheels and the track depends on the weight per wheel, and determines the force that can be applied before the wheels begin to slip.
- Speed: Up to a certain speed, the tractive effort is almost constant. As speed increases further, the current in the traction motor falls and hence so does the tractive effort.

B. Resistance: This force, which opposes the motion, comes from a variety of sources, the most important being friction in the axle bearings, air resistance, and resistance from the rail as the wheels roll along it.

Railway operators estimate resistance from experiments which measure the force needed to keep a train moving at a constant speed.

Relation of Tractive force and Speed & Resistance and Speed :

i. Tractive performance of ETR1000 of 25kV 50Hz and maximum tractive force is 370kN.
ii. RESISTANCE OF ETR1000 OF 25kV 50Hz and maximum resistance force is 60kN.



Graph 3: Performance of Tractive effort and Resistance ETR1000 High Speed Passenger Train

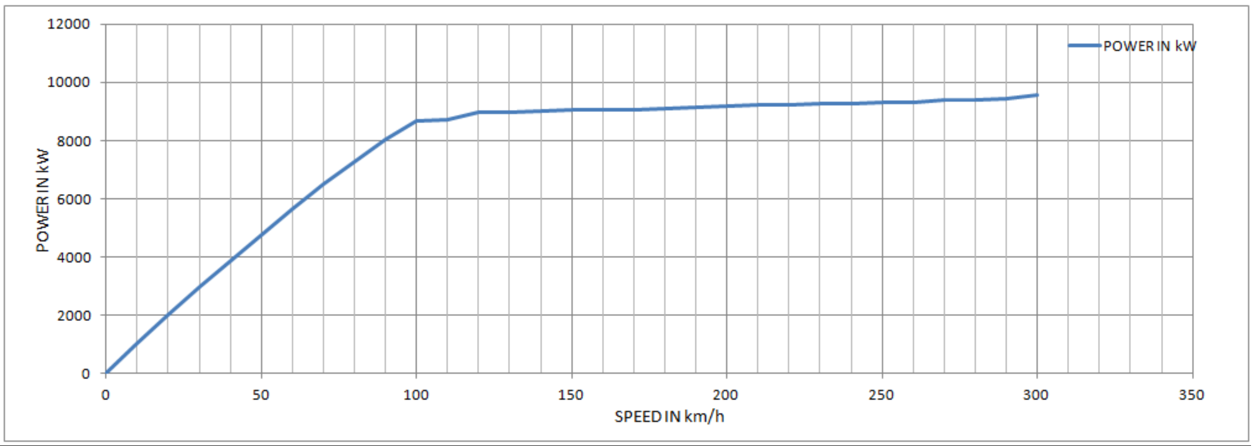
7.3.2 RELATION BETWEEN POWER AND SPEED:

From the above graph 4, we know the Maximum power of ETR 1000 High Speed Passenger Train is 9800 kW Consumed. And Speed varies at a time Power is varies.

From Theoretical Equation,

Power = Tractive Force * Speed

- $P = T * V$ [kW]



Graph 4: Maximum power of ETR 1000 High Speed Passenger Train

7.4 COMPARING OF ETR 1000 HIGH SPEED TRAIN

Comparing the ETR 1000 High Speed Passenger Train in two cases:

I. Without limit speed
II. With limit speed

7.4.1 RELATION OF SPEED V/S DISTANCE :

From the below graph 5, we know the relation of speed and distance.

a. SPEED V/S DISTANCE WITH ACTUAL LIMIT
b. SPEED V/S DISTANCE WITHOUT LIMIT
c. SPEED V/S DISTANCE WITH LIMIT

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h

<u>We comparing the speed with actual limit in two cases,</u>

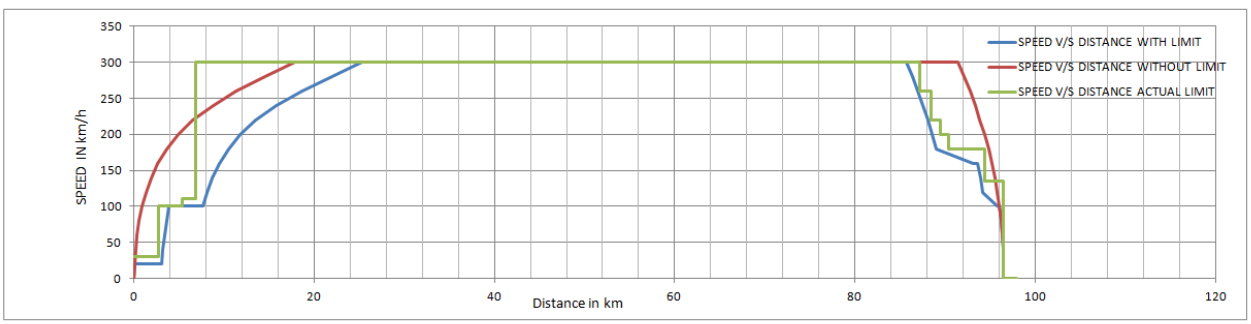
<u>First cases</u>,

We consider as a trial operation, it is not possible but we operated by applying theoretical methodology without limit speed for reach destination point with speed limit 300 km/h. And its maximum speed in FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line.

<u>Second cases</u>,

We operated by applying theoretical methodology with limit speed for reach destination point with speed limit is 300 km/h.

Finally, we comparing graph 5 to know performance of Speed with Distance.



Graph 5: Relation of Speed v/s Distance

7.4.2 REALTION 0F SPEED V/S TIME:

From the below graph 6, we know the relation between Speed v/s Time.

a. SPEED V/S TIME WITHOUT LIMIT.
b. SPEED V/S TIME WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h

We comparing the speed with actual limit in two cases,

First cases,

We consider as a trial operation, it is not possible, just operated with theoretical manner without limit speed for reach destination point Bologna Centrale

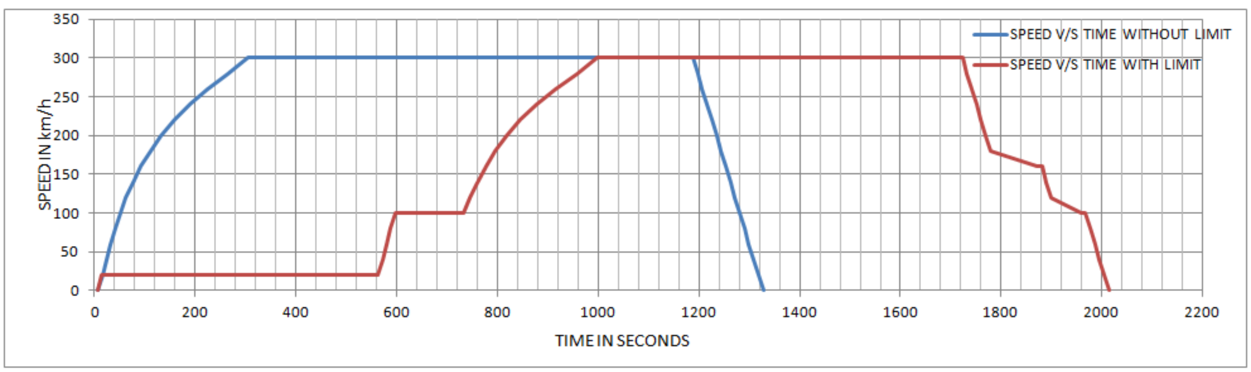
- Time taken is **1327 seconds / 22 minutes**

Second cases,

We consider as with limit speed for reach destination point Bologna Centrale

- Time taken is **2014 seconds / 33 minutes 30 seconds**

Finally, we comparing graph 6 to know performance of speed and Time.



Graph 6: Relation between Speed v/s Time

7.4.3 RELATION OF DISTANCE V/S TIME:

From the below graph 7, we know the relation between Distance v/s Time.

a. DISTANCE V/S TIME WITHOUT LIMIT.
b. DISTANCE V/S TIME WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h

We comparing the speed with actual limit in two cases,

First cases,

Without limit speed for reach destination point is Bologna Centrale

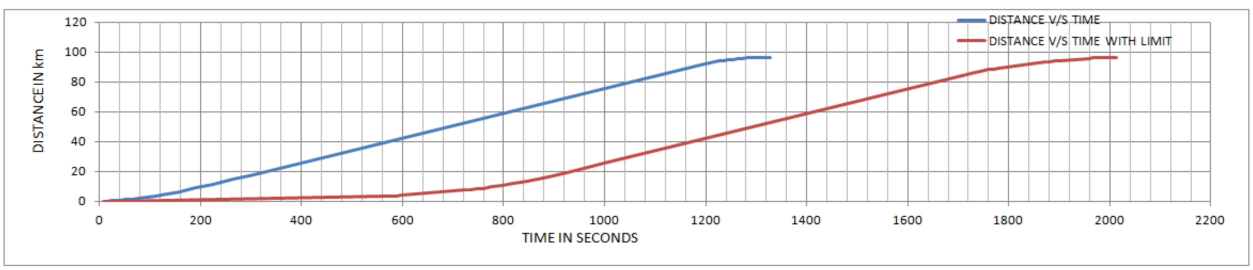
- Time taken is **1327 seconds / 22 minutes**

Second cases,

We consider as with limit speed for reach destination point Bologna Centrale

- Time taken is **2014 seconds / 33 minutes 30 seconds.**

Finally, we comparing graph 7 to know performance of Distance and Time.



Graph 7: Relation of Distance v/s Time

<u>RELATION OF ACCELERATION V/S DISTANCE</u>:

From the below graph 8, we know the relation between Acceleration v/s Distance

a. ACCELERATION V/S DISTANCE WITHOUT LIMIT.
b. ACCELERATION V/S DISTANCE WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h

From theory,

Acceleration = Force / mass

- ✓ $a = \frac{F}{M}$ [m/s2]

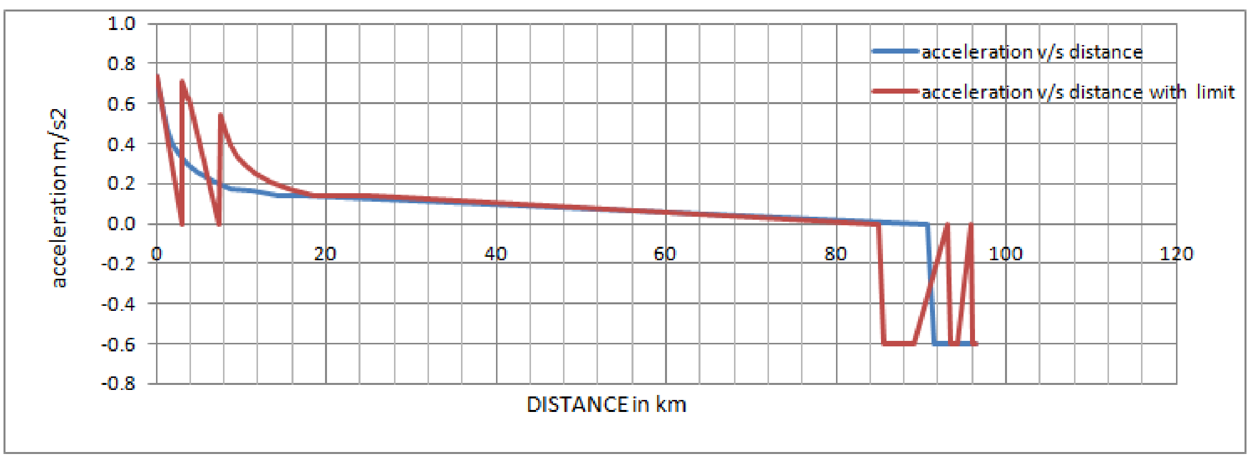
Δt = mass * speed / Traction force-Resistance force

- ✓ $\Delta t = \frac{M \, \Delta v}{T(vm) - R(vm)}$ [s]

Max Acceleration of ETR1000 High Speed Passenger Train = 0.739 m/s2

And constant de-acceleration ETR1000 High Speed Passenger Train = 0.6 m/s2

Finally, we comparing graph 8 to know performance of Acceleration and Distance.



Graph 8: Relation of Acceleration and Distance

RELATION OF ACCELERATION V/S TIME:

From the below graph 9, we know the relation between Acceleration v/s Time

a. ACCELERATION V/S TIME WITHOUT LIMIT.
b. ACCELERATION V/S TIME WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h

From theory,

Acceleration = Force / mass

- ✓ $a = \frac{F}{M}$ [m/s2]

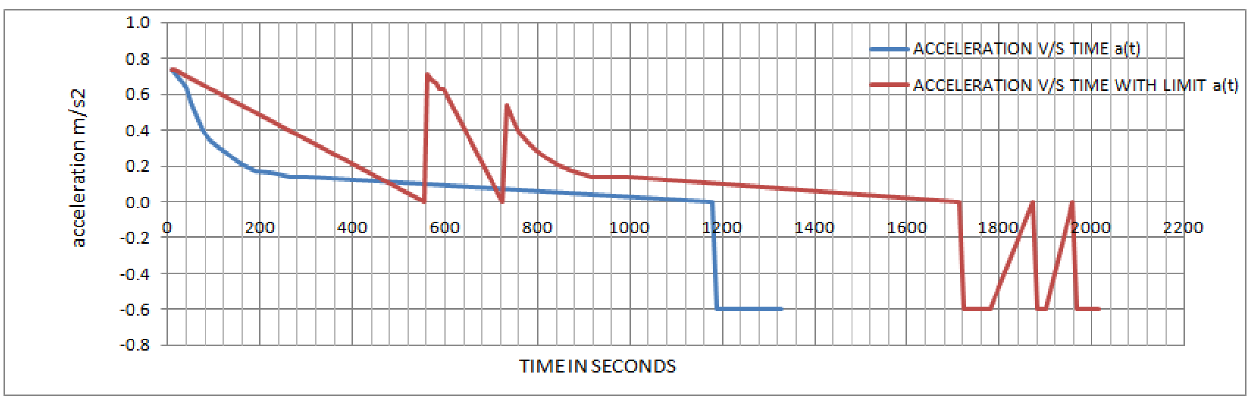
Δt = mass * speed / Traction force-Resistance force

- ✓ $\Delta t = \frac{M\,\Delta v}{T(vm)-R(vm)}$ [s]

Max Acceleration = 0.739 m/s2

And constant de-acceleration = 0.6 m/s2

Finally, we comparing graph 9 to know performance of Acceleration and Time.



Graph 9: Relation of Acceleration and Time

7.4.4 RELATION OF ENERGY CONSUMPTION INPUT V/S DISTANCE:

From the below graph 10, we know the relation between Energy consumption input v/s Distance.

a. ENERGY CONSUMPTION INPUT V/S DISTANCE WITHOUT LIMIT.
b. ENERGY CONSUMPTION INPUT V/S DISTANCEWITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h

From theory of Equation,

Energy input or engine = power * time

✓ $E\ input = P * t$ [kW-h]

<u>First cases,</u>

Without limit speed for reach destination point is Bologna Centrale

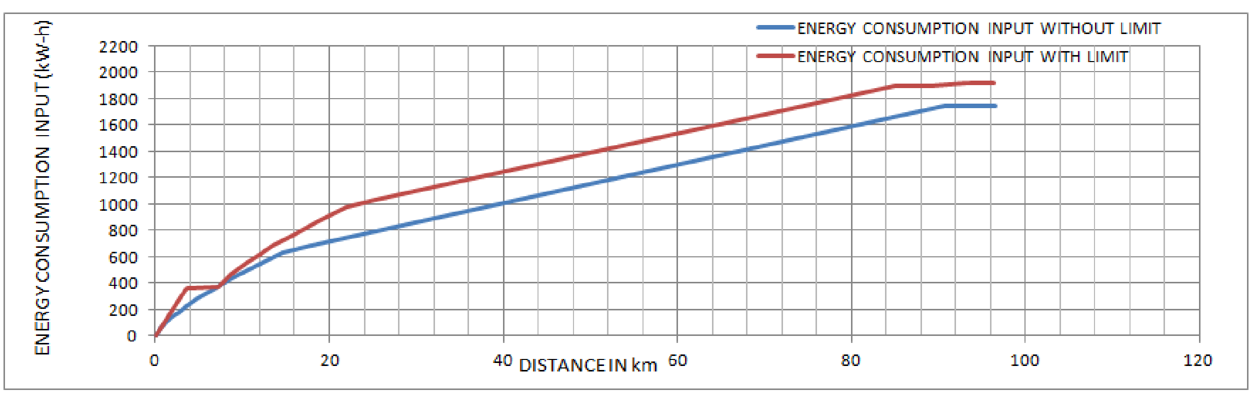
- Energy consumption input is consumed **1746** [kW-h]

<u>Second cases,</u>

We consider as with limit speed for reach destination point Bologna Centrale

- Energy consumption input is consumed **1918** [kW-h]

Finally, we comparing graph 10 to know performance of Energy consumption input v/s Distance and gradually increases.



Graph 10: Relation of Energy Consumption Input v/s Distance

RELATION OF ENERGY CONSUMPTION OUTPUT V/S DISTANCE:

From the below graph 11, we know the relation between Energy consumption output v/s Distance.

a. ENERGY CONSUMPTION OUTPUT V/S DISTANCEWITHOUT LIMIT.
b. ENERGY CONSUMPTION OUTPUT V/S DISTANCEWITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h

Assuming Efficiency is 90 %

From theory of Equation,

Energy output or wheel = energy input * efficiency

✓ $E\ output = E\ input * \eta$ [kW-h]

First cases,

Without limit speed for reach destination point is Bologna Centrale

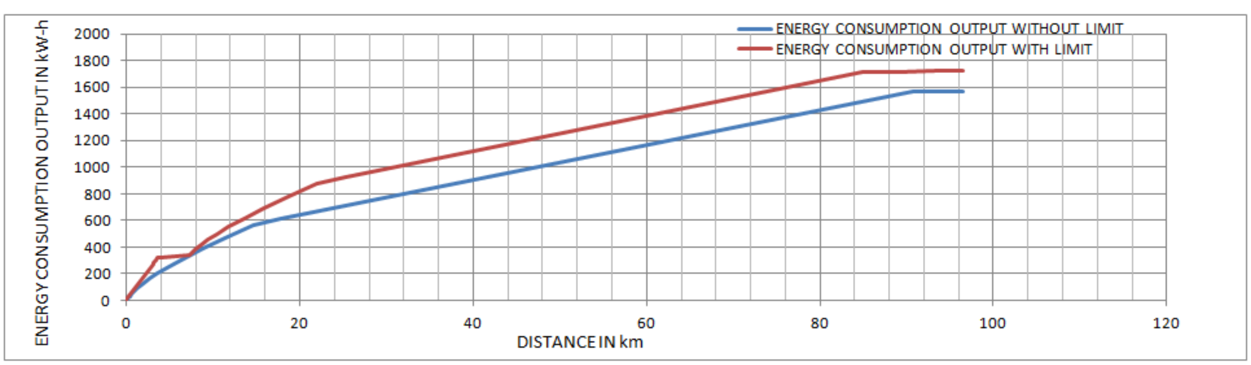
- Energy consumption output is consumed **1571** [kW-h]

Second cases,

We consider as with limit speed for reach destination point Bologna Centrale

- Energy consumption output is consumed **1726** [kW-h]

Finally, we comparing graph 11 to know performance of Energy consumption output v/s Distance and gradually increases.



Graph 11: Relation between Energy Consumption Output v/s Distance

COMMERCIAL SPEED OF ETR1000 HIGH SPEED PASSENGER TRAIN:

Equation of Commercial Speed (with limit speed) is

Vc = Distance of origin to destination / Total travelling time of origin to destination

✓ $Vc = \frac{L}{ta+tr+tf+ts}$ [m/s] or [km/h]

- ❖ ETR1000 (without limit speed) = **262** [km/h]
- ❖ ETR1000 (with limit speed) = **172** [km/h]

Characteristics of ETR1000 High Speed Passenger Train:

From this table 3 we are showing performance of ETR1000 High Speed Passenger Train mainly on Distance, Time and Energy Consumed are analysis on without limit speed with limit speed.

To reach Bologna Central Station from Firenze Santa Maria Novella distance is 96.484km and its takes normal time is around 32mins.

TABLE 3: As we shown tabular column in below

TRAIN NAME	ETR1000	
	WITHOUT LIMIT	WITH LIMIT
FIRENZE SMN TO BOLOGNA.C.LE		
MASS (Ton)	490	490
MAX LINE SPEED (km/h)	300	300
DISTANCE (km)	**96.484**	**96.484**
TIME (Seconds)	**1327**	**2014**
COMMERCIAL SPEED (km/h)	262	172
ENERGY CONSUMED ENGINE (kW)	**1746**	**1918**
ENERGY CONSUMED WHEEL (kW)	**1571**	**1726**
POWER (kW)	9583	9583

7.4.6 EFFECT OF PASSENGERS:

The process of high energy consumption, mainly on

i. Full strength of Passengers are not available then Energy consumed high
ii. Equipments are used regularly, for not required situations for eg. Air conditioner, Fans, Electric Supply, Motors.

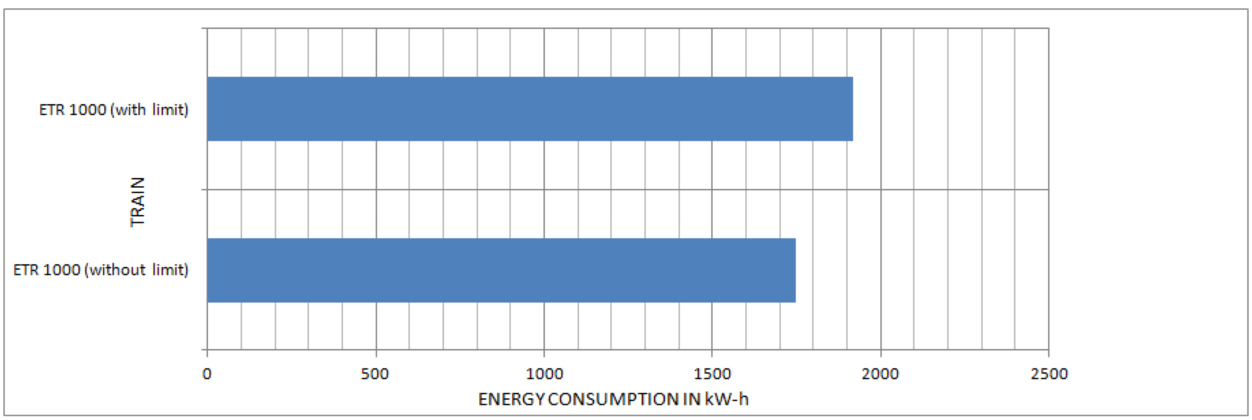
If positive,

It depends on passenger for saving energy.

Monitoring, Controlling and Consuming Energy due to available passengers

Focusing on CRITERIA OF PASSENGERS:

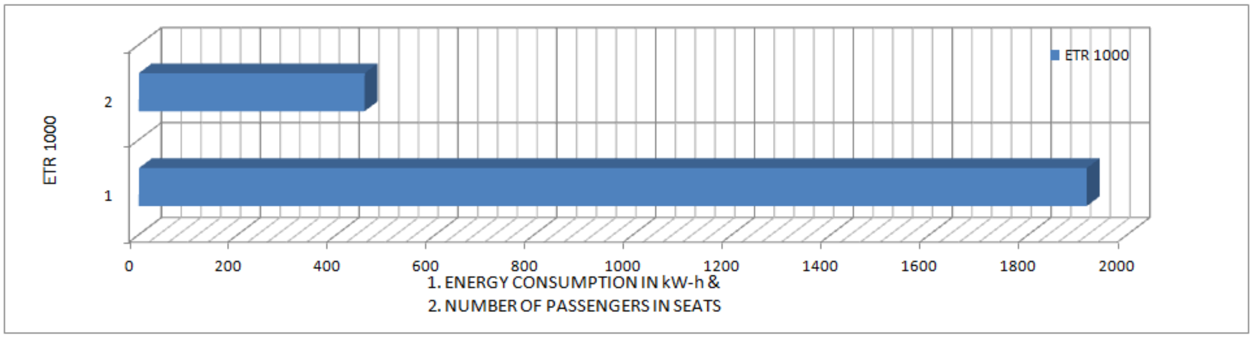
From the below graph 12, we are comparing the without limit and with limit speed of Energy consumption.



Graph 12: Relation between Speed v/s Energy Consumption

Operating solution:

- The passengers are less then Energy will be consumed less.
- The passengers are high then Energy will be consumed more.



Graph 13: Relation between ETR1000 Train and Energy Consumption & Number of Passengers

From the graph 13, we knowing the Number of Passenger of train and Energy Consumption of ETR 1000 high speed passenger train (with limit speed).

7.5 ETR 1000 High Speed Passenger Train comparing ETR 500, ICE 3 Velaro E & SNFC TGV-THALYS (PABK)

Comparing the four trains to know

a. Performance of trains
b. Behaviour of trains
c. Energy Consumption of trains

7.5.1 RELATION OF SPEED V/S DISTANCE:

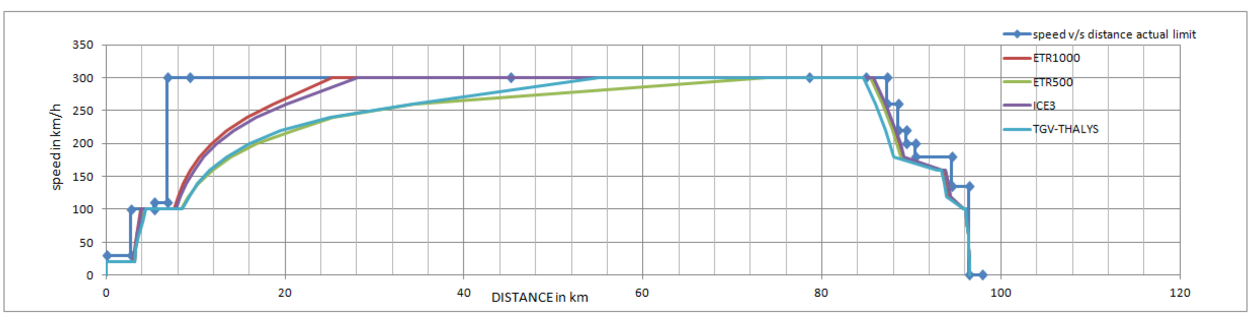
From the below graph 14, we know performance of Speed and Distance with ETR1000.

a) SPEED V/S DISTANCE WITH ACTUAL LIMIT.
b) SPEED V/S DISTANCE WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

We comparing the speed and distance with actual limit, we consider as with limit speed for reach destination point with speed limit 300km/h. And ETR1000& ICE 3Velaro E are performing same speed with distance, but ETR 500 and TGV-THALYS are not moving in same speed and distance with ETR1000 Train.

Finally, we comparing graph 14 to know performance of Speed and Distance with ETR1000.



Graph 14: Relation of Speed v/s Distance

7.5.2 RELATION OF SPEED V/S TIME:

From the below graph 15, we know performance of Speed and Tim with ETR 1000.

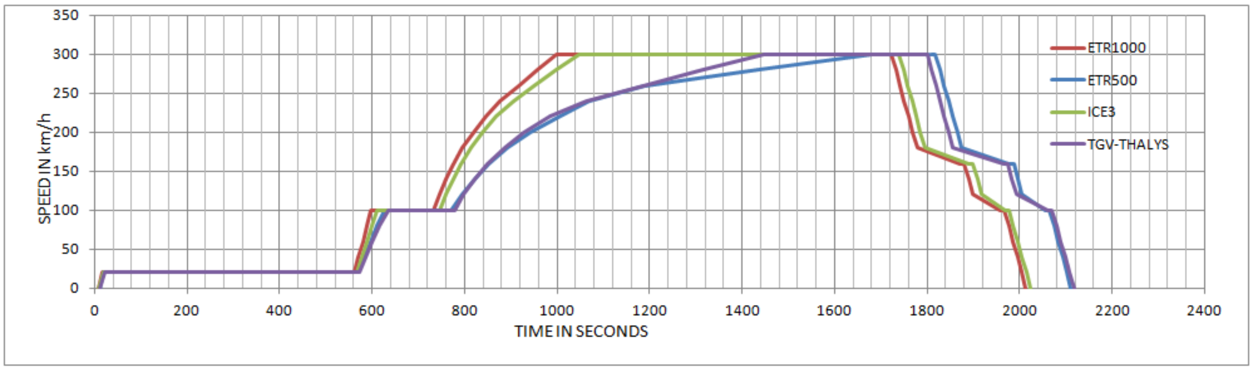
a) SPEED V/S TIME WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

We comparing the Speed and Time with actual limit, we consider as with limit Speed for reach destination point with speed limit 300km/h.

- ETR1000 and ICE 3Velaro E are performing same speed and Time.
- ETR 500 and TGV-THALYS are not moving in same speed and Time with ETR 1000 Train.

Finally, we comparing graph 15 to know performance of Speed and Time with ETR 1000.



Graph 15: Relation of Speed v/s Time

<u>7.5.3 RELATION OF DISTANCE V/S TIME</u>:

From the below graph 16, we know the performance of Speed and Time with ETR 1000.

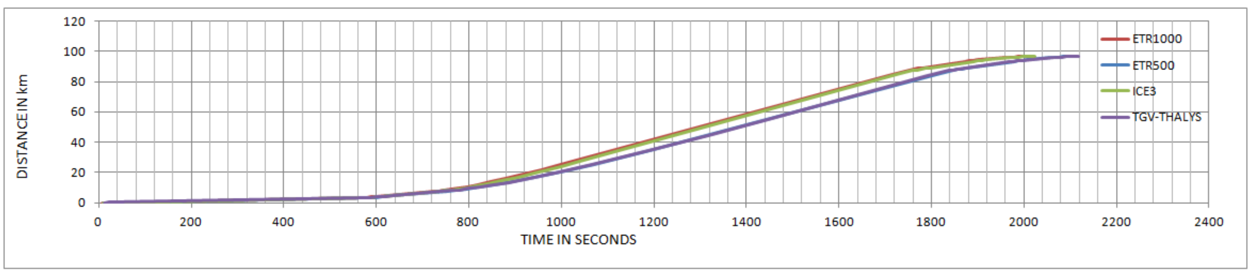
a) DISTANCE V/S TIME WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

We comparing the Distance and Time with actual limit, we consider as with limit Speed for reach destination point with speed limit 300km/h.

- ETR1000 and ICE 3Velaro E are performing same Distance and Time
- ETR 500 and TGV-THALYS are not moving in same Distance and Time with ETR 1000 Train.

Finally, we comparing graph 16 to know performance of Speed and Time with ETR 1000.



Graph 16: Relation of Distance v/s Time

7.5.4 RELATION OF ENERGY CONSUMPTION INPUT V/S DISTANCE:

From the below graph 17, we know the Energy Consumption input and Distance

a) ENERGY CONSUMPTION INPUT V/S DISTANCE WITH LIMIT

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

From theory of Equation,

Energy input or engine = power * time

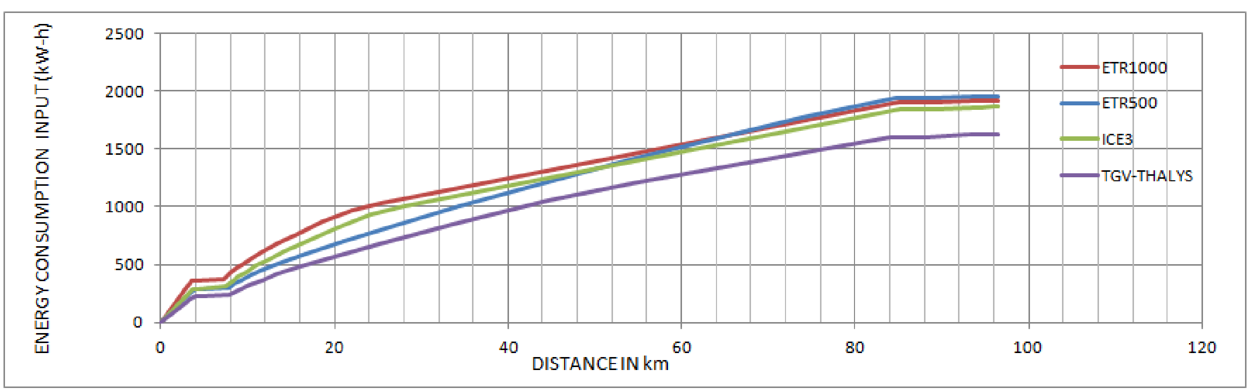
- ✓ $E\ input = P * t$ [kW-h]

We comparing the Energy Consumption input and Distance with actual limit, we consider as with limit Speed for reach destination point at the same time does not exceed 300km/h.

In this case, when we comparing the performance of high speed passenger train

- ➢ ETR 500 train is more Energy consumed than ETR 1000, because of number of seats is increases then Energy will be increases.
- ➢ And remaining ICE 3 Velaro E and TGV-THALYS are less Energy consumed than ETR 1000 Train.

Finally, we comparing graph 17 to know performance of Energy Consumption input and Distance with ETR 1000 Train.



Graph 17: Relation of Energy Consumption input and Distance

7.5.5 RELATION OF ENERGY CONSUMPTION OUTPUT V/S DISTANCE:

From the below graph 18, we know the Energy Consumption output and Distance.

a) ENERGY CONSUMPTION OUTPUT V/S DISTANCE WITH LIMIT

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

Assuming, Efficiency is 90 %

From theory of Equation,

Energy output or wheel = energy input * efficiency

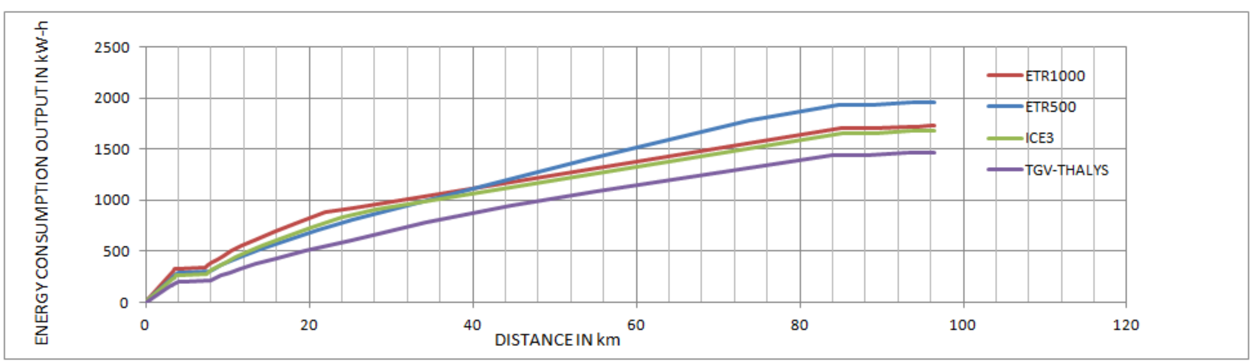
✓ $E\ output = E\ input * \eta$ [kW-h]

We comparing the Energy Consumption output and Distance with actual limit, we consider as with limit Speed for reach destination point with speed limit 300km/h.

In this case, when we comparing,

- ETR 500 train is more Energy consumed than ETR 1000, because of number of seats is increases then Energy will be increases.
- And remaining ICE 3 Velaro E and TGV-THALYS are less Energy consumed than ETR 1000 Train.

Finally, we comparing graph 18 to know performance of Energy Consumption output and Distance with ETR 1000 Train.



Graph 18: Relation of Energy Consumption output and Distance

COMMERCIAL SPEED OF HIGH SPEED PASSENGER TRAINS:

Equation of Commercial Speed (with limit speed) is

Vc = Distance of origin to destination / Total travelling time of origin to destination

$$Vc = \frac{L}{ta+tr+tf+ts} \qquad \text{[m/s] or [km/h]}$$

- ETR1000 = **172** [km/h]
- ETR500 = **166** [km/h]
- ICE 3 VELARO E = **172** [km/h]
- TGV THALYS = **164** [km/h]

7.5.6 Characteristics OF ETR 1000 AND ETR500, ICE3 and TGV-THALYS:

Some Analyse are done by using characteristics of four different high speed passenger trains.

As a theoretically, we calculated some physical methods to derive Distance, Time, Acceleration and Energy consumption of both engine and wheel.

TABLE 4: Characteristics OF ETR 1000 AND ETR500, ICE3 and TGV-THALYS

TRAIN NAME	ETR 1000	ETR5 500	ICE 3 Velaro E	TGV – THALYS
	SPEED LIMIT	SPEED LIMIT	SPEED LIMIT	SPEED LIMIT
FIRENZE SMN TO BOLOGNA.C.LE				
EMPTY MASS (Ton)	454	576	439	383
MASS WITH PASSENGERS (Ton)	490	664	474	428
MAX. LINE SPEED (km/h)	300	300	300	300
DISTANCE (km)	96.484	96.484	96.484	96.484
TIME (Seconds)	**2014**	**2097**	**2024**	**2124**
COMMERCIAL SPEED (km/h)	172	166	172	164
ENERGY CONSUMED ENGINE (kW)	**1918**	**2202**	**1866**	**1644**
ENERGY CONSUMED WHEEL (kW)	**1726**	**1981**	**1680**	**1479**
CAPACITY	**457 SEATS**	**574 SEATS**	**405 SEATS**	**377 SEATS**
CAR FORMATION	8 car (Distributed)	Two Locomotive and 11 Trailer	8 car (Distributed)	10 car (Concentrated)
POWER (kW)	9583	8167	8750	5458

7.5.7 EFFECT OF PASSENGERS:

The process of high energy consumption, mainly on

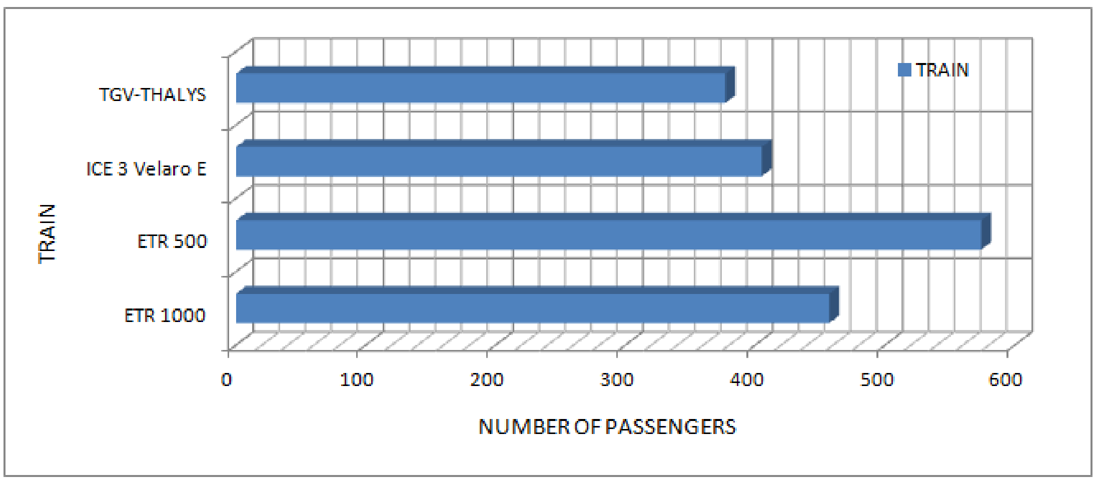
b) Full strength of Passengers are not available then Energy consumed high
c) Equipments are used regularly for not required situations eg. Air Conditioner, Fans, Electric Supply, Motors.

If positive,

- It depends on passenger for saving energy.
- Monitoring, Controlling and Consuming Energy due to available passengers

Focusing on CRITERIA OF PASSENGERS:

From the below graph 19, we are showing a relation between Different Train and Number of Passenger Train. Number of Passengers data collected from Technical specification of train, energy consumption is calculated data.

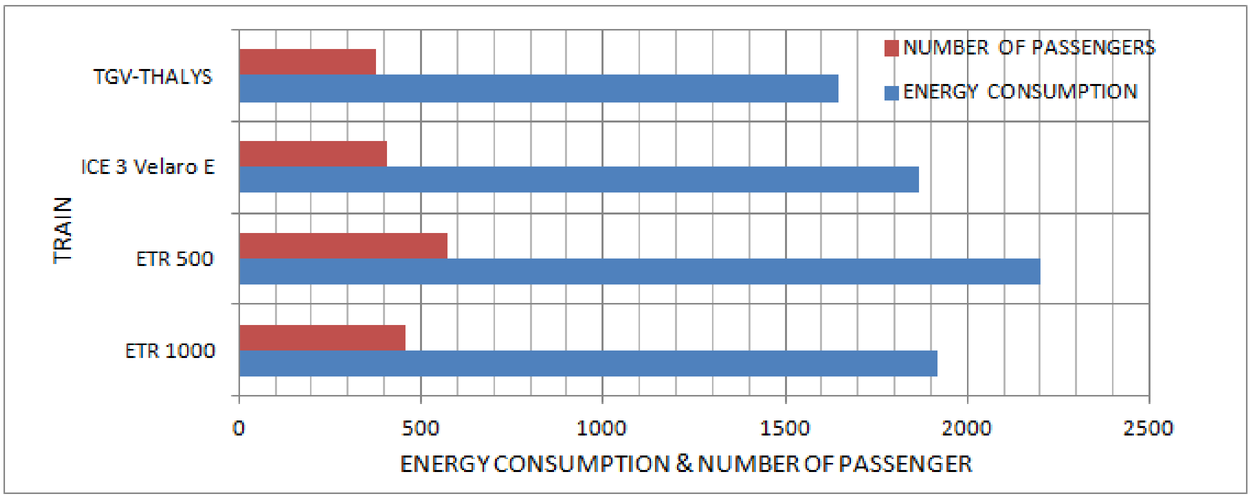


Graph 19: Relation between Different Train and Number of Passenger Train

Operating solution:

- The passengers are less then Energy will be consumed less.
- The passengers are high then Energy will be consumed more.

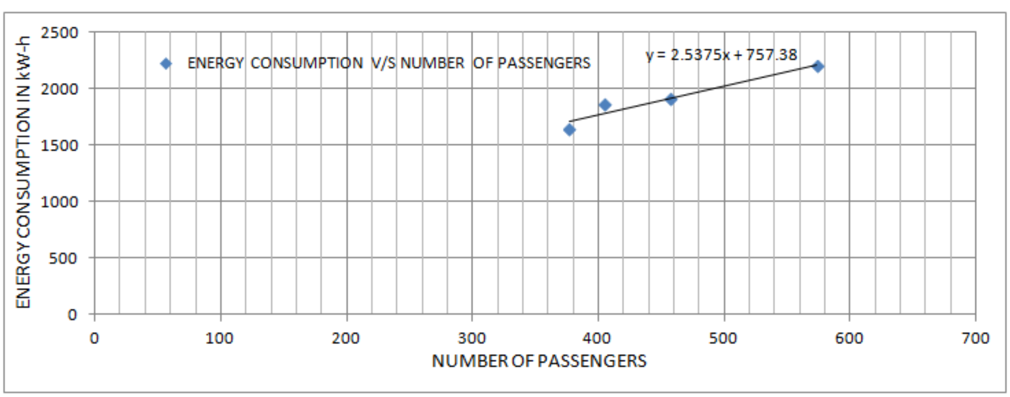
From the graph 20, consider to know about energy consumed of each train with varies of capacity.



Graph 20: Relation between Different Train and Energy Consumption & Number of Passengers

If it happens,

a) Energy consumption depends upon number of passengers are available in train.
b) Energy consumption is gradually increases due to number of passengers are increases.



Graph 21: Relation between Energy consumption and Number of Passengers

CHAPTER 8

RAIL WEIGHT BOGIES

Definition of RAIL WEIGHT BOGIES:

Railway bogies are hardly noticed by the average passenger but they are an essential part of the train, its drive system and its guidance mechanism. A standard railway vehicle will have two bogies, generally located near the vehicles ends. Each bogie is a 4-wheeled or 6-wheeled truck that provides the support for the vehicle body and which is used to provide its traction and braking. Each carriage has two bogies. The bogies support the mass of the vehicle, use the wheels to guide it along the track and provide some degree of cushioning against the shocks transmitted from the track during motion.

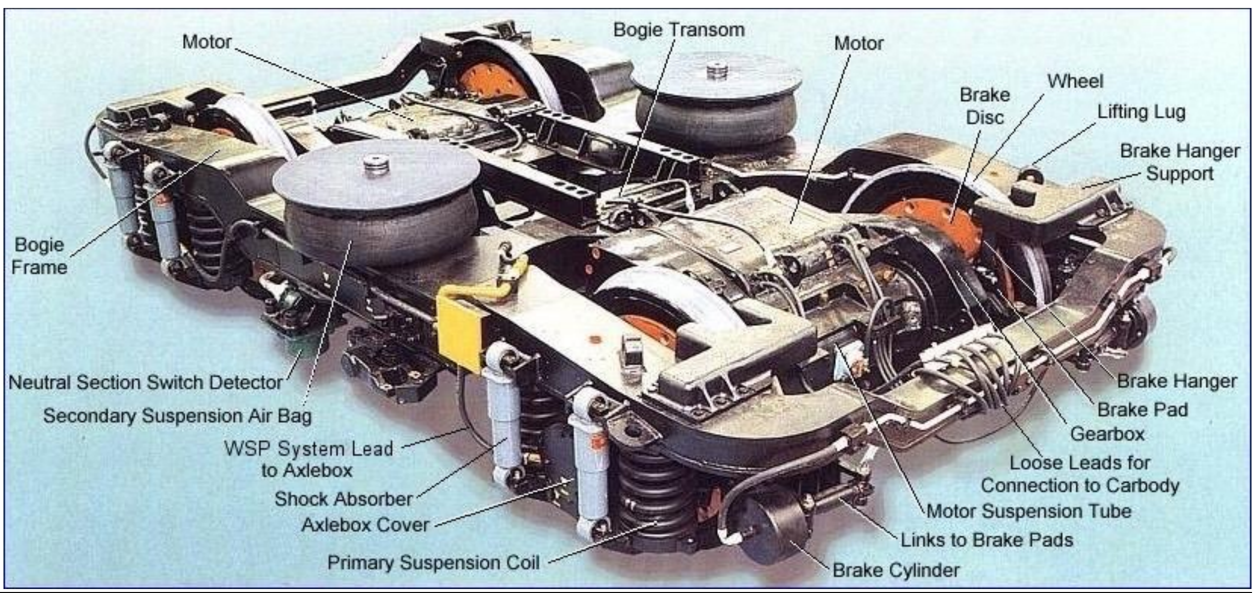


Figure 10: Railway Motor Bogie of an Electric vehicle (source 17 in reference pg 93)

Bogies come in many shapes and sizes but it is in its most developed form as the motor bogie of an electric or diesel locomotive or an EMU. Here it has to carry the motors, brakes and suspension systems all within a tight envelope. It is subjected to severe stresses and shocks and may have to run at over 300 km/h in a high speed application. (Source 18 in reference pg 93)

Comparing the rail weight bogies in the graph are includes:

Minor, medium and major segments of regional, commuter and heavy high speed trains applications. (Source 19 in reference pg 93)

8.1 ANALYSIS OF RAIL BOGIES

Considering in two different scenarios as

A. Motored Bogie
B. Trailer Bogie

A. MOTORED BOGIE :

Motored Bogies weight are considered by using Siemens and Bombardier catalogues

Mainly on motored bogie considering is Bogies Weight, Car body Weight and Total Weight of Bogies. (Source 21 in reference pg 94)

Fig 11 shows in below ETR 1000 motored bogie from Bombardier catalogue

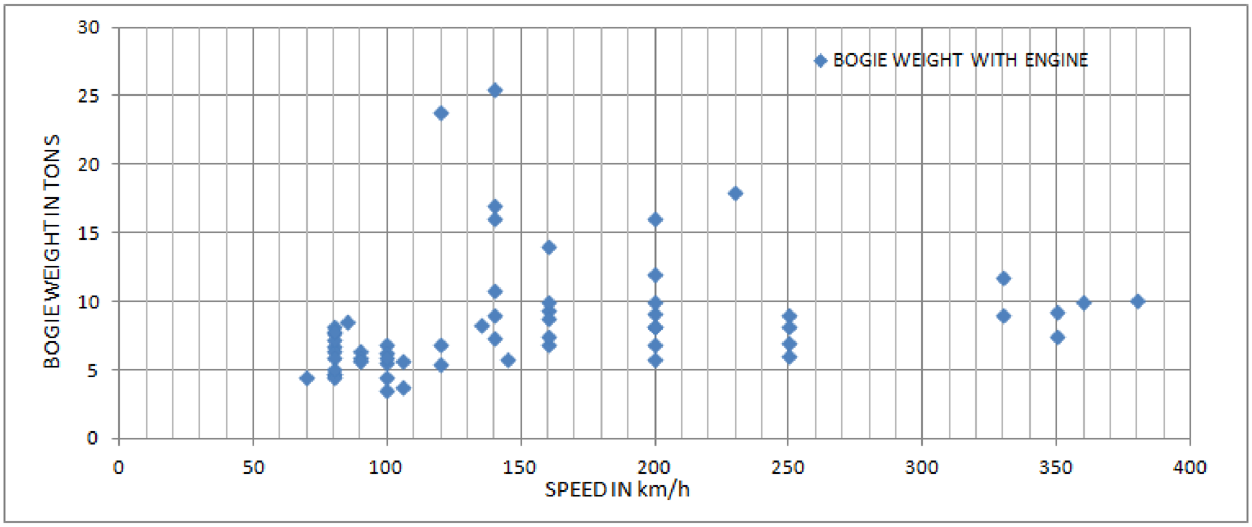
Analyzing the trailer bogie weight reduction process

Figure 11: Railway ETR1000 Motor Bogie of an Electric vehicle (source 20 in reference pg 93)

1 RELATION WITH BOGIE WEIGHT V/S SPEED :

From the below graph 22 of motor rail, we know difference of weight bogies in tons for different segment to speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies.

Bogie weights are considered from 4tons to 26tons and speed is considered from 70km/h to 380km/h.

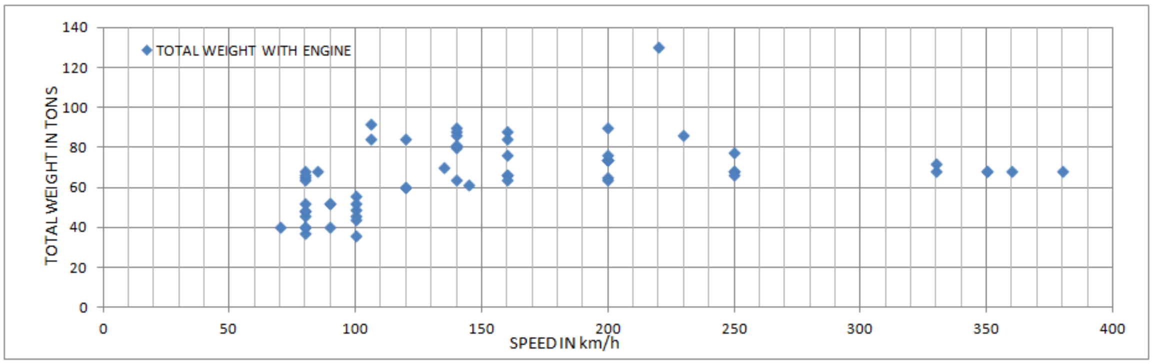


Graph 22: Relation with Bogie Weight v/s Speed

2 RELATION WITH TOTAL WEIGHT V/S SPEED :

From the below graph 23 of motor rail, we know difference of total weight in tons for different segment to speed in km/h are Passenger rail, Light rail, Heavy rail, Locomotive, High speed train, Passenger coaches.

Total weights are considered from 37tons to 130tons and speed is considered from 70km/h to 380km/h.

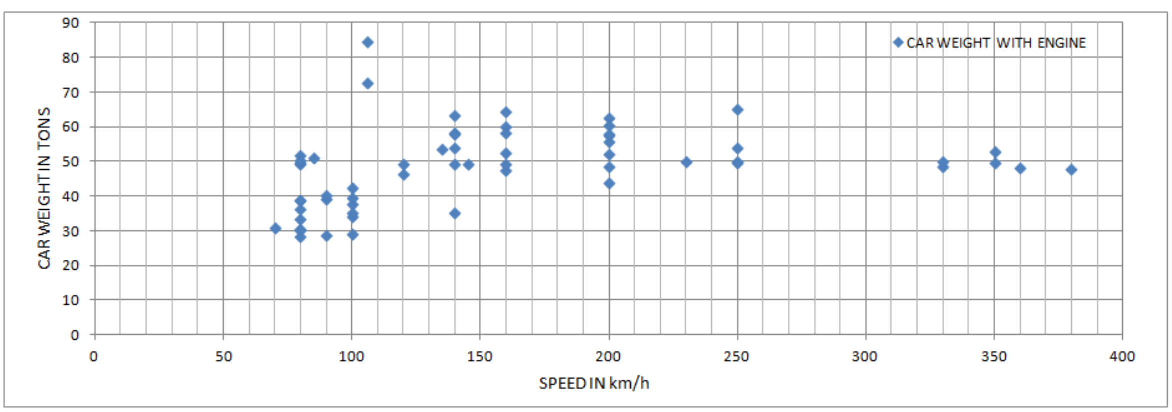


Graph 23: Relation with Total Weight v/s Speed

3 RELATION WITH CAR BODY WEIGHT V/S SPEED :

From the below graph 24 of motor rail, we know difference of car body weight in tons for different segment to speed in km/h are Passenger rail, Light rail, Heavy rail, Locomotive, High speed train, Passenger coaches.

Car weights are considered from 28tons to 85tons and speed are considered from 70km/h to 380km/h.



Graph 24: Relation with Car Body Weight v/s Speed

B) **TRAILER BOGIE :**

Trailer Bogies weight are considered by using Siemens and Bombardier catalogues

Mainly on Trailer Bogie considering is Bogies Weight, Car Body Weight and Total Weight of Bogies. (Source 21 in reference pg 94)

Figure 12 shows the Trailer Bogie of Germany train bogie from Bombardier catalogue

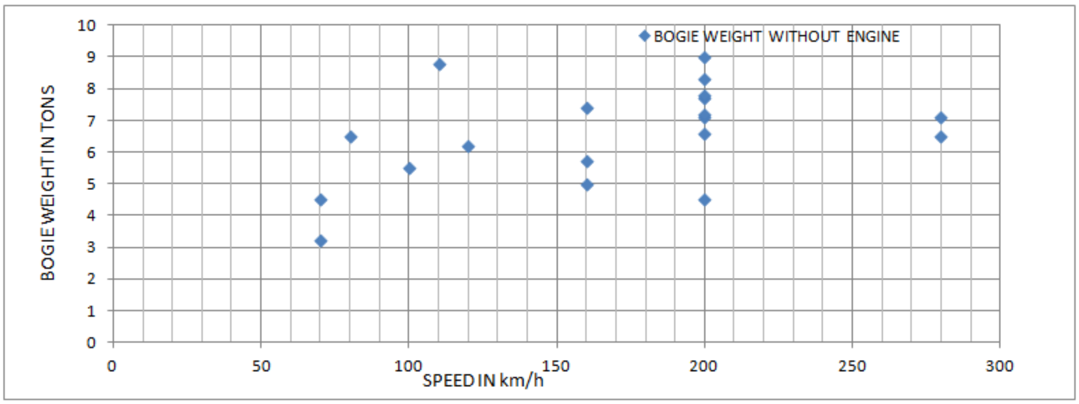
Analyzing the trailer bogie to know weight reduction process

Figure 12: Railway Trailer Bogie of an Electric vehicle

1 RELATION WITH BOGIE WEIGHT V/S SPEED

From the below graph 25 of Trailer, we know difference of weight bogies in tons for different segment to speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies.

Bogie weights are considered from 3tons to 9tons and speed are considered from 70km/h to 280km/h.

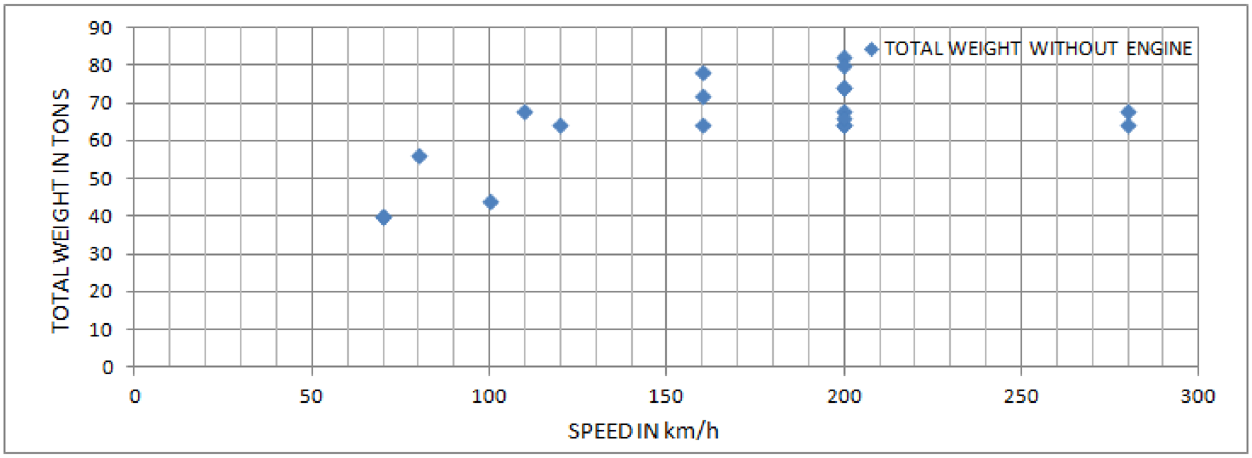


Graph 25: Relation with Bogie Weight v/s Speed

2 RELATION WITH TOTAL WEIGHT V/S SPEED

From the below graph 26 of Trailer, we know difference of total weight in tons for different segment to speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies.

Total weights are considered from 40tons to 85tons and speed is considered from 70km/h to 280km/h.

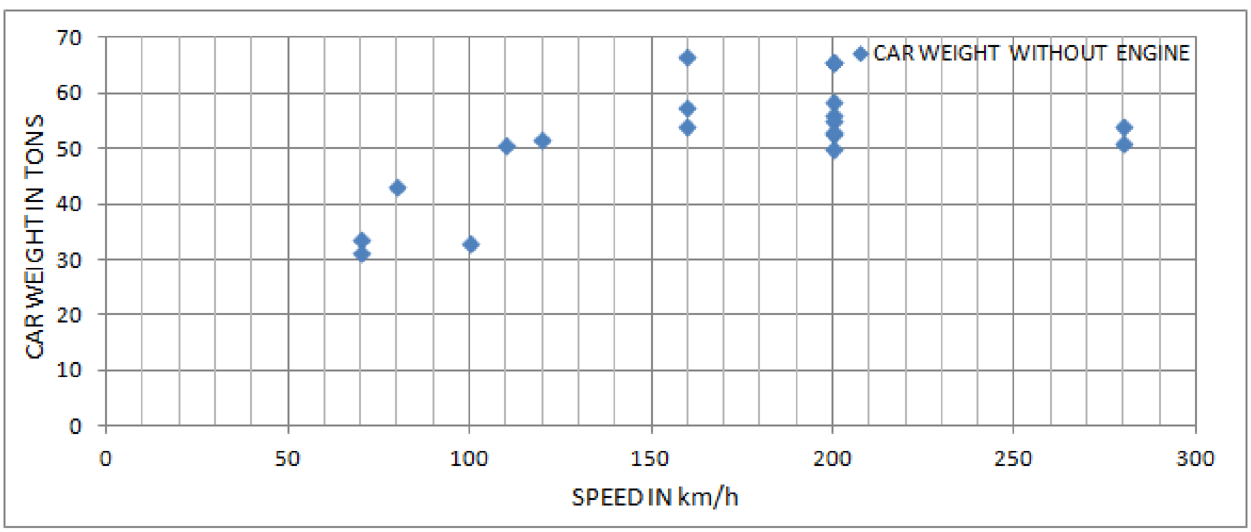


Graph 26: Relation with Total Weight v/s Speed

3 RELATION WITH CAR BODY WEIGHT V/S SPEED

From the below graph 27 of Trailer, we know difference of car body weight in tons for different segment to speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies.

Car weights are considered from 30tons to 65tons and speed are considered from 70km/h to 280km/h.



Graph 27: Relation with Car Body Weight v/s Speed

8.2 ANALYSIS OF BOGIES ON HIGH SPEED TRAIN

Comparing the rail weight bogies in the graph are includes:

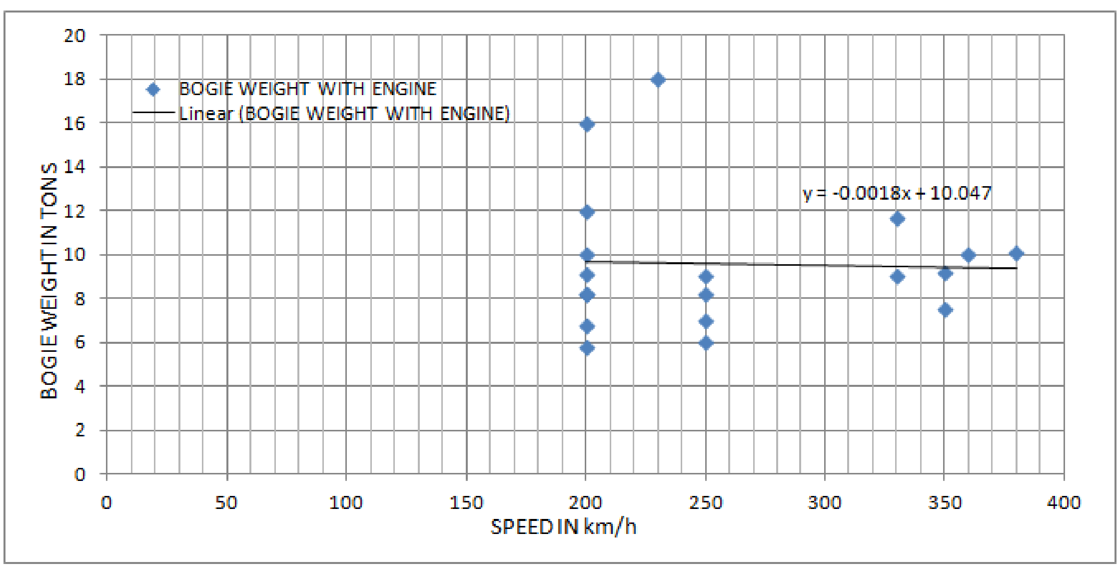
- Major segments of High speed trains applications (Considering from 200 km/h to 400 km/h).
- Actual high speed rail bogie is starts from 250 km/h. (source 22 in reference pg 94)
    - Passenger rail bogies
    - Light rail bogies
    - Heavy rail bogies
    - Locomotive bogies
    - High speed train bogies
    - Passenger coaches bogies

8.2.1 MOTORED BOGIE:

1 RELATION WITH BOGIE WEIGHT V/S SPEED

From the below graph 28 of motor rail, we know difference of weight bogies in tons for segment to high speed rail bogie speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies. Trend line shows the bogies weight is constant, decreasing or increasing.

Bogie weights are considered from 6tons to 18tons and speed are considered from 200km/h to 380km/h.

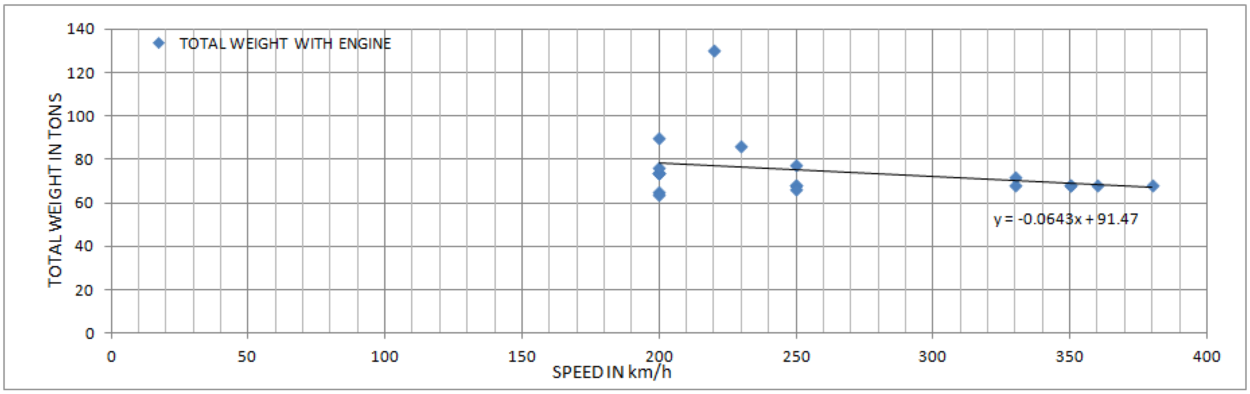


Graph 28: Relation with Bogie Weight v/s Speed

2 RELATION WITH TOTAL WEIGHT V/S SPEED

From the below graph 29 of motor rail, we know difference of total weight in tons for segment to high speed rail bogie speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies. And Trend line shows the total weight is constant, decreasing or increasing.

Total weights are considered from 62tons to 130tons and speed is considered from 200km/h to 380km/h.



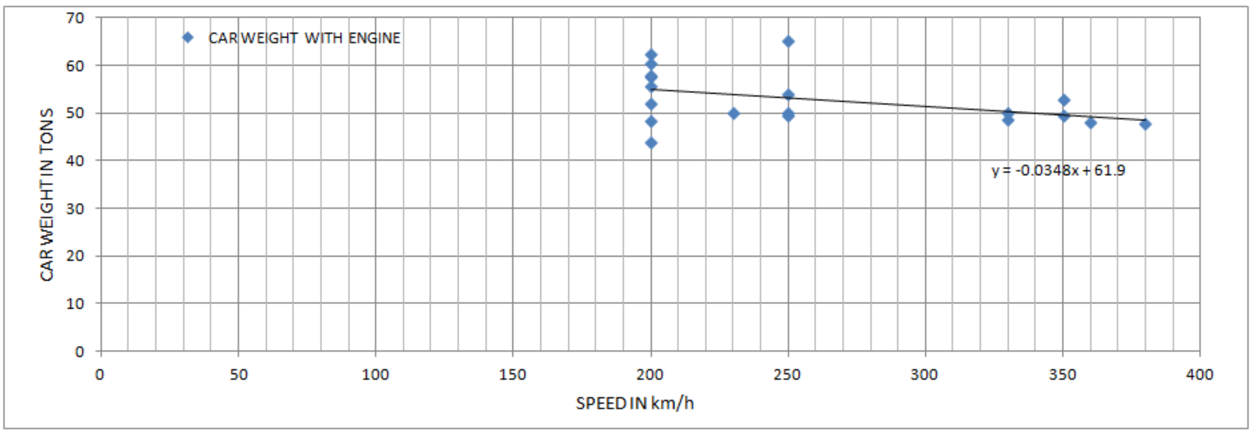
Graph 29: Relation with Total Weight v/s Speed

3 RELATION WITH CAR BODY WEIGHT V/S SPEED:

From the below graph 30 of motor rail, we know difference of car body weight in tons for segment to high speed rail bogie speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies.

Trend line shows the car weight is constant, decreasing or increasing.

Car weights are considered from 42tons to 65tons and speed are considered from 200km/h to 380km/h.



Graph 30: Relation with Car Body Weight v/s Speed

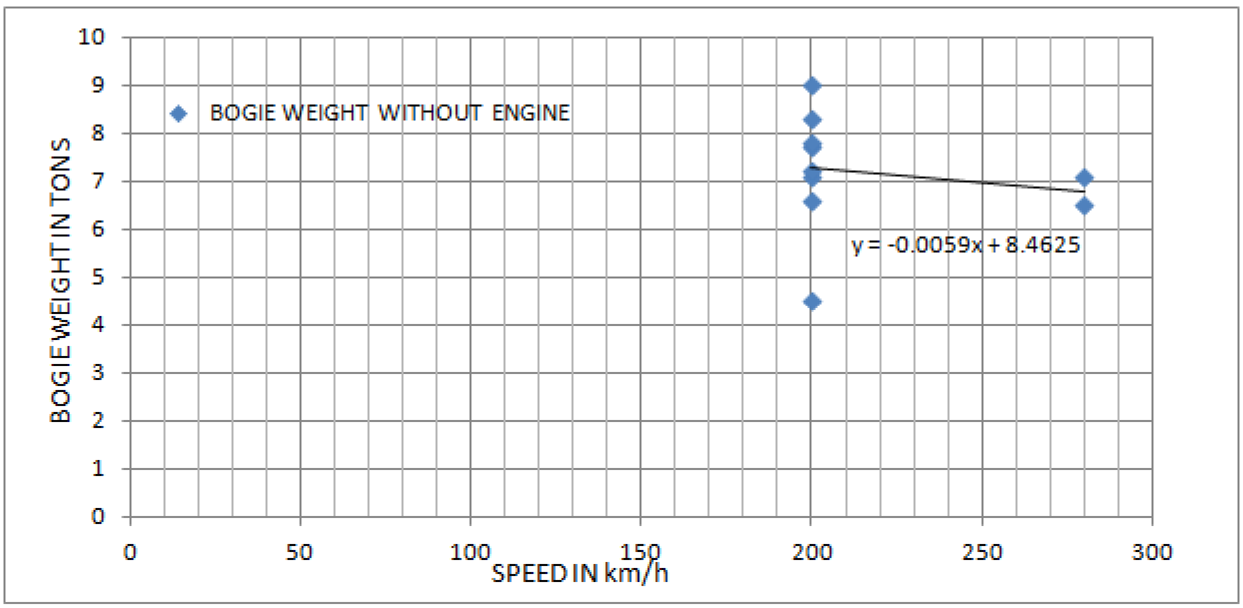
8.2.2 TRAILER BOGIE:

1 RELATION WITH BOGIE WEIGHT V/S SPEED:

From the below graph 31 of trailer rail, we know difference of weight bogies in tons for segment to high speed rail bogie speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies.

Trend line shows the bogies weight is constant, decreasing or increasing.

Bogie weights are considered from 4.5tons to 9tons and speed are considered from 200km/h to 280km/h.



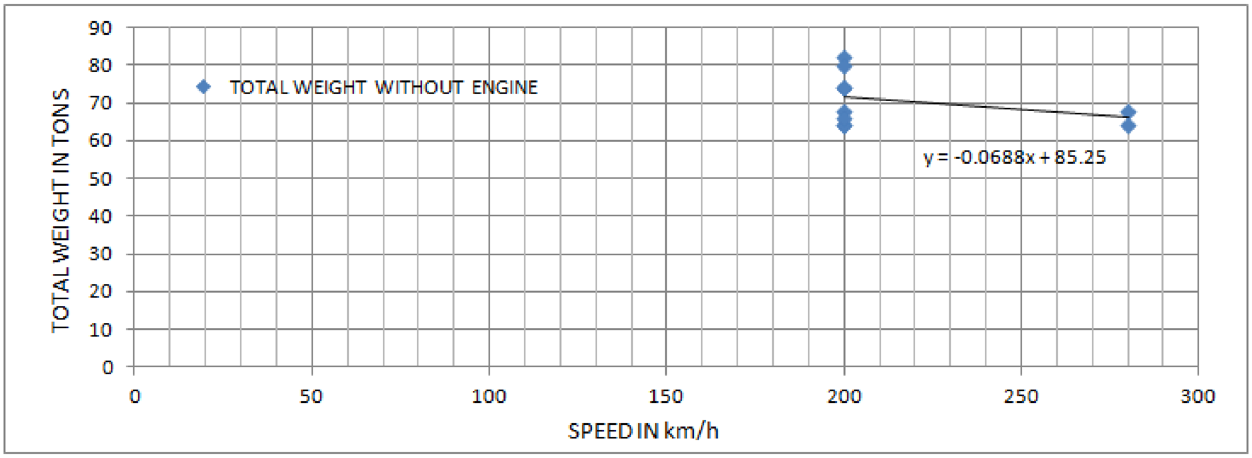
Graph 31: Relation with Bogie Weight v/s Speed

2 RELATION WITH TOTAL WEIGHT V/S SPEED:

From the below graph 32 of motor rail, we know difference of total weight in tons for segment to high speed rail bogie speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies.

Trend line shows the total weight is constant, decreasing or increasing.

Total weights are considered from 62tons to 84tons and speed is considered from 200km/h to 280km/h.



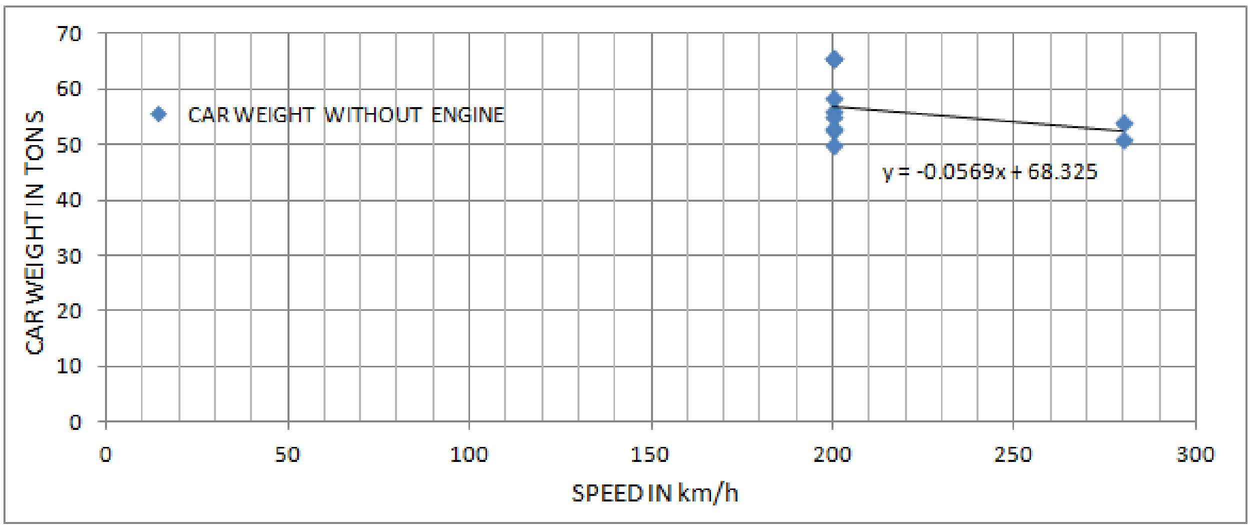
Graph 32: Relation with Total Weight v/s Speed

3 RELATION WITH CAR BODY WEIGHT V/S SPEED:

From the below graph 33 of motor rail, we know difference of car body weight in tons for segment to high speed rail bogie speed in km/h are Passenger rail bogies, Light rail bogies, Heavy rail bogies, Locomotive bogies, High speed train bogies, Passenger coaches bogies.

Trend line shows the car weight is constant, decreasing or increasing.

Car weights are considered from 50tons to 65tons and speed are considered from 200km/h to 280km/h.



Graph 33: Relation with Car Body Weight v/s Speed

CHAPTER 9

WEIGHT REDUCTION

Definition of WEIGHT REDUCTION:

The benefit of light weighting is said to be marginal when considering high-speed trains. A run cycle based analysis method is used to evaluate energy savings, wear reduction, downsizing possibilities and reduced travel time as function of reduced weight. Depending on operating conditions, the relation between weight reduction and energy consumption for high-speed trains is shown to be equivalent of that for automobiles.

Analyzing the process of weight reduction, we consider on reduced weight than actual weight of ETR 1000, ETR 500, ICE 3 Velaro E and TGV-THALYS high speed passenger trains.

9.1 ANALYSIS OF WEIGHT REDUCTION ON HIGH SPEED PASSENGER TRAIN ARE ETR1000, ETR500, ICE3 AND TGV-THALYS

We assume the weight reduction of high speed passenger train. 10 % of weight is reduced of actual mass weight with passenger of high speed train and 10 % seats reduced of Actual Number of passenger seats.

To find performance of each train and comparing with ETR 1000 and ETR 500, ICE 3 Velaro E & TGV-THALYS are:

9.1.1 RELATION OF SPEED V/S DISTANCE:

From the below graph 34, we know the speed and distance.

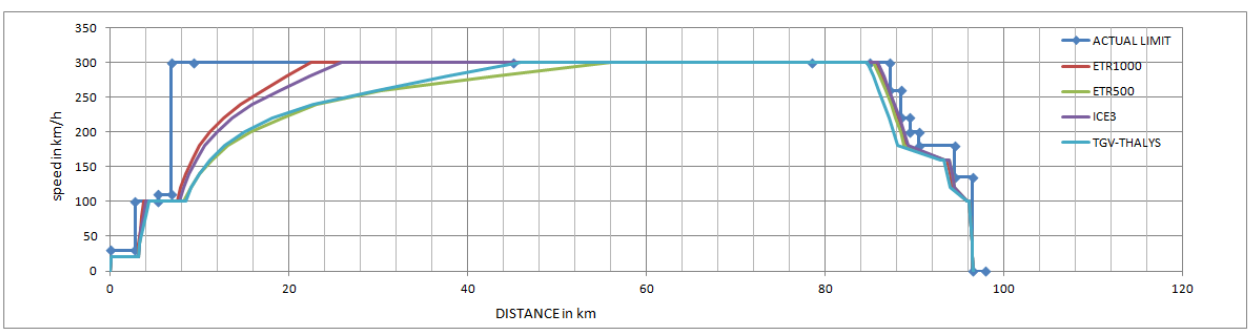
a) SPEED V/S DISTANCE WITH LIMIT

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

We comparing the speed and distance with actual limit, consider as with limit speed for reach destination point with speed limit 300km/h.

- ETR1000 and ICE 3 Velaro E are performing same speed with distance.
- ETR 500 and TGV-THALYS are not moving in same speed and distance with ETR 1000 Train.

Finally, we comparing graph 34 to know performance of Speed and Distance with ETR 1000.



Graph 34: Relation of Speed and Distance (10% Weight Reduced)

9.1.2 RELATION OF SPEED V/S TIME:

From the below graph 35, we know the Speed and Time.

a. SPEED V/S TIME WITH LIMIT

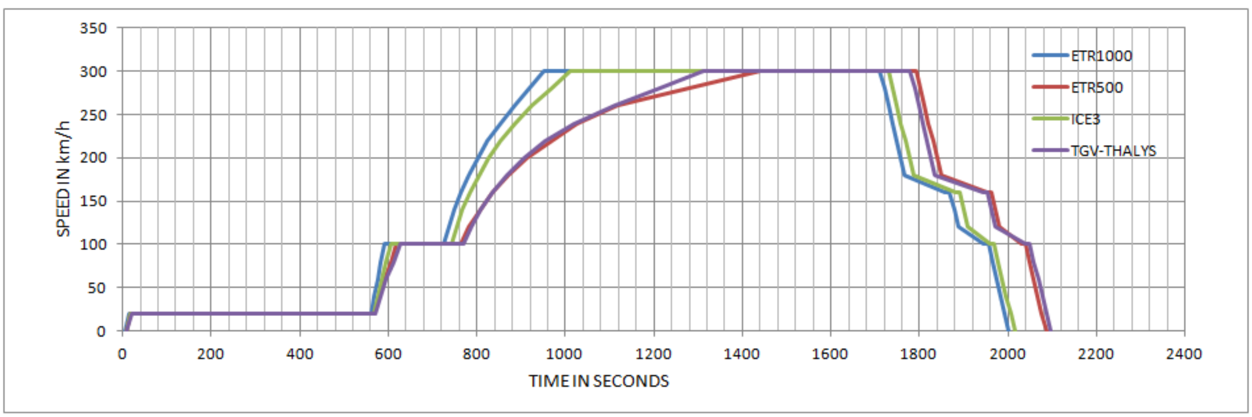
Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

We comparing the Speed and Time with actual limit,

We consider as with limit Speed for reach destination point with speed limit 300km/h.

- ETR1000 and ICE 3Velaro E are performing same speed and Time.
- ETR 500 and TGV-THALYS are not moving in same speed and Time with ETR 1000 Train.

Finally, we comparing graph 35 to know performance of Speed and Time with ETR 1000.



Graph 35: Relation of Speed and Time (10% Weight Reduced)

9.1.3 RELATION OF DISTANCE V/S TIME:

From the below graph 36, we know the Distance and Time.

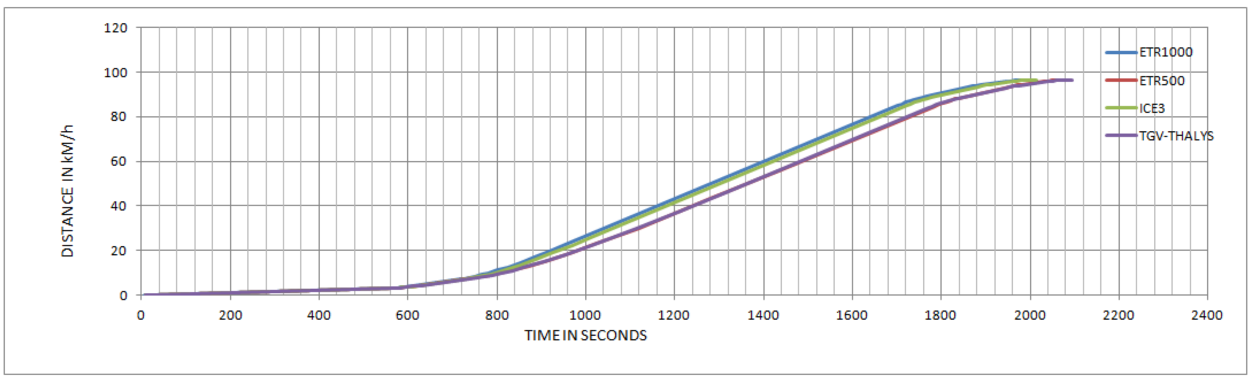
a) DISTANCE V/S TIME WITH LIMIT

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

We consider as with limit Speed for reach destination point with speed limit 300km/h.

- ETR1000 and ICE 3 Velaro E are performing same Distance and Time
- ETR 500 and TGV-THALYS are not moving in same Distance and Time with ETR 1000 Train.

Finally, we comparing graph 36 to know performance of Speed and Time with ETR 1000.



Graph 36: Relation of Speed and Time (10% Weight Reduced)

9.1.4 RELATION OF ENERGY CONSUMPTION INPUT V/S DISTANCE:

From the below graph 37, we know the Energy Consumption Input and Distance.

a) ENERGY CONSUMPTION INPUT V/S DISTANCE WITH LIMIT

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

From theory of Equation,

Energy input or engine = power * time

✓ $E\ input = P * t$ [kW-h]

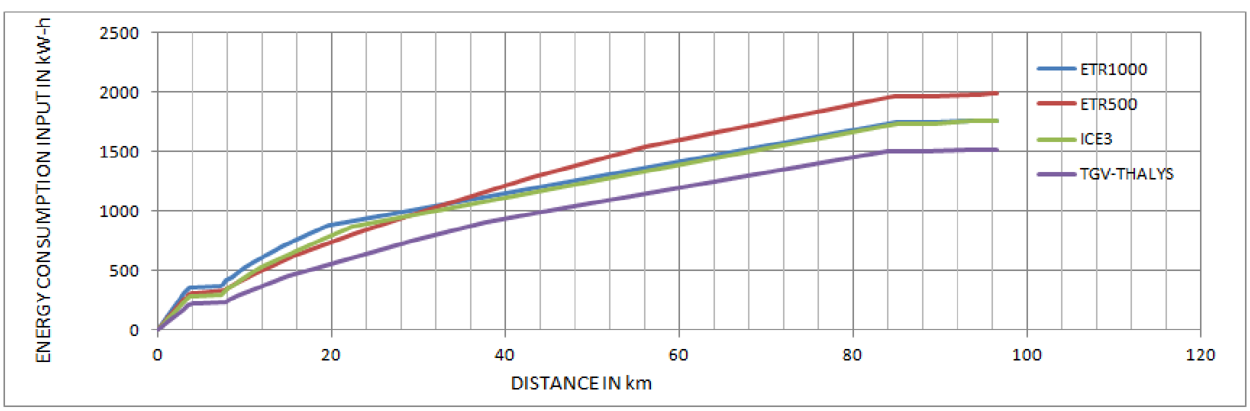
We comparing the Energy Consumption input and Distance with actual limit,

We consider as with limit Speed for reach destination point with speed limit 300km/h.

In this case, when we comparing,

- ETR 500 train is more Energy consumed than ETR 1000, because of number of seats is increases then Energy will be increases.
- Remaining ICE 3 Velaro E and TGV-THALYS are less Energy consumed than ETR 1000 Train.

Finally, we comparing graph 37 to know performance of Energy Consumption Input and Distance with ETR 1000 Train.



Graph 37: Relation of Energy Consumption Input and Distance (10% Weight Reduced)

9.1.5 RELATION OF ENERGY CONSUMPTION OUTPUT V/S DISTANCE:

From the below graph 38, we know the Energy Consumption Output and Distance

a) ENERGY CONSUMPTION OUTPUT V/S DISTANCE WITH LIMIT

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 300km/h.

Assuming, Efficiency is 90 %

From theory of Equation,

Energy output or wheel = energy input * efficiency

✓ $E\ output = E\ input * \eta$ [kW-h]

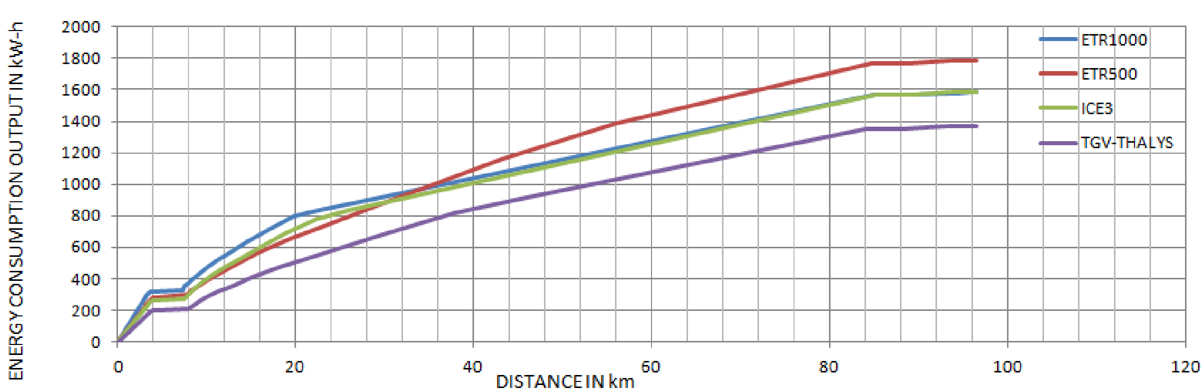
We comparing the Energy Consumption output and Distance with actual limit,

We consider as with limit Speed for reach destination point with speed limit 300km/h.

In this case, when we comparing

- ETR 500 train is more Energy consumed than ETR 1000, because of number of seats is increases then Energy will be increases.
- Remaining ICE 3 Velaro E and TGV-THALYS are less Energy consumed than ETR 1000 Train.

Finally, we comparing graph 38 to know performance of Energy Consumption Output and Distance with ETR 1000 Train.



Graph 38: Relation of Energy Consumption Output and Distance (10% Weight Reduced)

COMMERCIAL SPEED (10% WEIGHT REDUCED) OF HIGH SPEED PASSENGER TRAINS:

Equation of Commercial Speed (10% of weight reduce with limit speed) is

Vc = Distance of origin to destination / Total travelling time of origin to destination

$$Vc = \frac{L}{ta+tr+tf+ts} \qquad [m/s] \text{ or } [km/h]$$

- ETR1000 = **174** [km/h]
- ETR500 = **168** [km/h]
- ICE 3 VELARO E = **173** [km/h]
- TGV THALYS = **166** [km/h]

As we discussed above all performances in this below table:

From the below table 5 we showing a characteristics of high speed trains ETR1000, ETR500, ICE 3 and TGV-THALYS mainly on Speed, Distance, Time and Energy Consumption of input and output.

TABLE 5: Characteristics OF WEIGHT REDUCED HIGH SPEED PASSENGER TRAIN

TRAIN NAME	ETR 1000			ETR5 500			ICE 3 Velaro E			TGV – THALYS		
	WITH SPEED LIMIT			WITH SPEED LIMIT			WITH SPEED LIMIT			WITH SPEED LIMIT		
FIRENZE SMN TO BOLOGNA. C.LE	ACTUAL MASS IN TONS	WEIGHT REDUCED MASS (TONS)	Percent Age (%)	ACTUAL MASS IN TONS	WEIGHT REDUCED MASS (TONS)	Per Cent age (%)	ACTUAL MASS IN TONS	WEIGHT REDUCED MASS (TONS)	Per Cent age (%)	ACTUAL MASS IN TONS	WEIGHT REDUCED MASS (TONS)	Per Cent age (%)
WEIGHT REDUCED MASS WITH PASSENGERS (Ton)	490	441	10	664	597	10	474	427	10	428	385	10
MAX. LINE SPEED (km/h)	300			300			300			300		
DISTANCE (km)	96.484			96.484			96.484			96.484		
TIME (Seconds)	**2013**	**2001**	**0.6**	**2097**	**2072**	**1.2**	**2023**	**2009**	**0.7**	**2124**	**2093**	**1.5**
COMMERCIAL SPEED (km/h)	172	174	1.2	166	168	1.2	172	173	0.6	164	166	1.2
ENERGY CONSUMED ENGINE (kW)	**1918**	**1760**	**8.2**	**2202**	**1996**	**9.4**	**1866**	**1706**	**8.6**	**1644**	**1519**	**7.6**
ENERGY CONSUMED WHEEL (kW)	**1726**	**1584**	**8.2**	**1981**	**1796**	**9.4**	**1680**	**1536**	**9.4**	**1479**	**1367**	**7.6**
CAPACITY	**457**	**412**	**10**	**574**	**517**	**10**	**405**	**365**	**10**	**377**	**340**	**10**
CAR FORMATION	8 car (Distributed)			Two Locomotive and 11 Trailer (Concentrated)			8 car (Distributed)			10 car (Concentrated)		
POWER (kW)	9583			8167			8750			5458		

9.1.6 BENEFITS OF WEIGHT REDUCTION:

The process of less energy consumption, mainly on weight reduction

- Full strength of Passengers are not available then Energy consumed less
- Equipment eg.. Air Conditioner, fans, others etc.. are used regularly for not required situations

If positive,

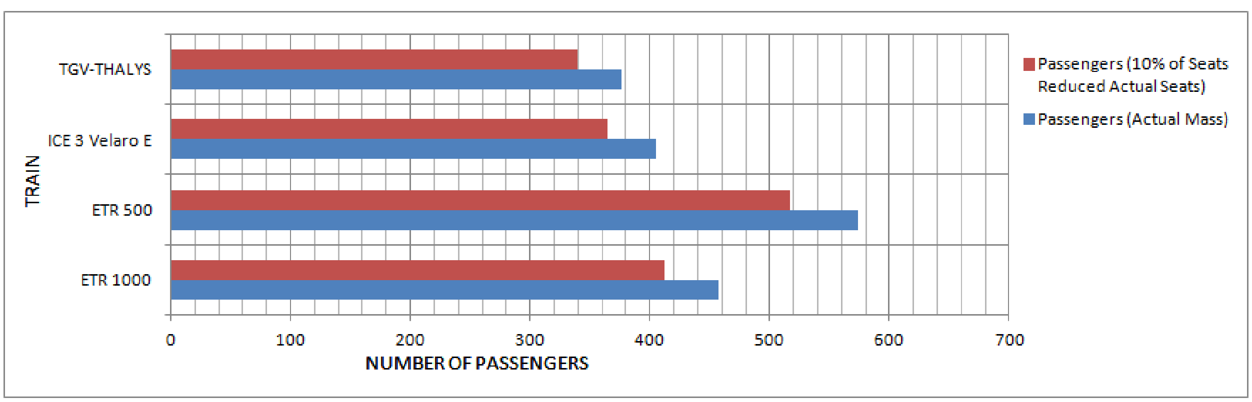
- It depends on passenger for saving energy.
- Monitoring, Controlling and Consuming Energy due to available passengers

Focusing on CRITERIA OF PASSENGERS:

1) Weight reduction is main focus on performances
2) Less energy consumption
3) Tractive effort will give more better
4) Passenger seats

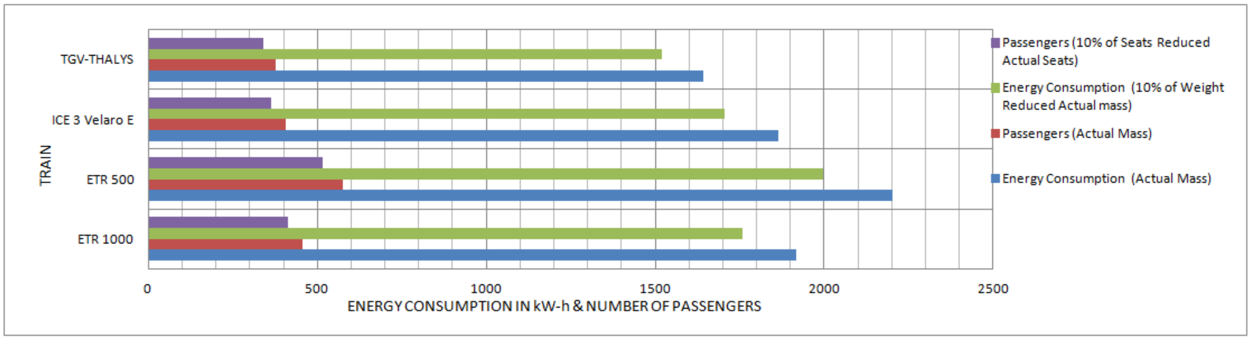
Analyzing the Performance of Energy consumption due to available passengers in high speed train:

From the below graph 39 we are showing a relation between Different Train and Number of Passenger Train. Highest capacity of train ETR 500 is 517 seats than ETR 1000 is 412 seats.



Graph 39: Graph of actual Seats and 10% of Seats Reduced with Relation between Different Train and Number of Passenger Train

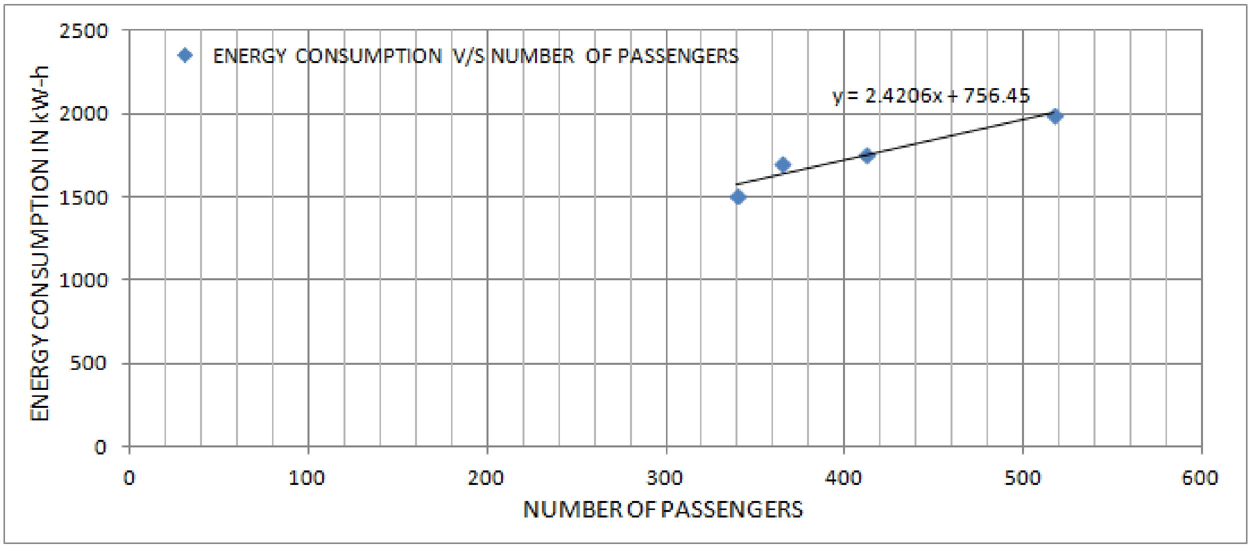
From the graph 40, consider to know about energy consumed of each train with varies of capacity.



Graph 40: Graph of Actual Mass and 10% of reduced weight with Relation between different Train and Energy Consumed & Number of Passengers

From the graph 41, consider to know about energy consumed of each train with varies of capacity.

- Energy consumption depends upon number of passengers are available in train.
- Energy consumption is gradually increases due to number of passengers.



Graph 41: Trend line with Relation between Energy Consumed and Number of Passengers

CHAPTER 10

FUTURE SCENERIO

FUTURE SCENERIO: (HIGH SPEED LINE: FIRENZE SMN TO BOLOGNA CENTRALE)

10.1 ETR1000 High Speed Passenger Train (detailing) components:

Two operations done for future scenario are:

A. 330 km/h maximum speed (Maximum Line Speed for Operation)
B. 360 km/h maximum speed (Design Speed European standards for Operation)

Figure 13**: ETR1000 High Speed Passenger Train** (source 17 in reference pg 92)

From below table 6, we are showing components of ETR1000 High Speed Train are Weight, Seat Capacity of Train, Power and Electric System.

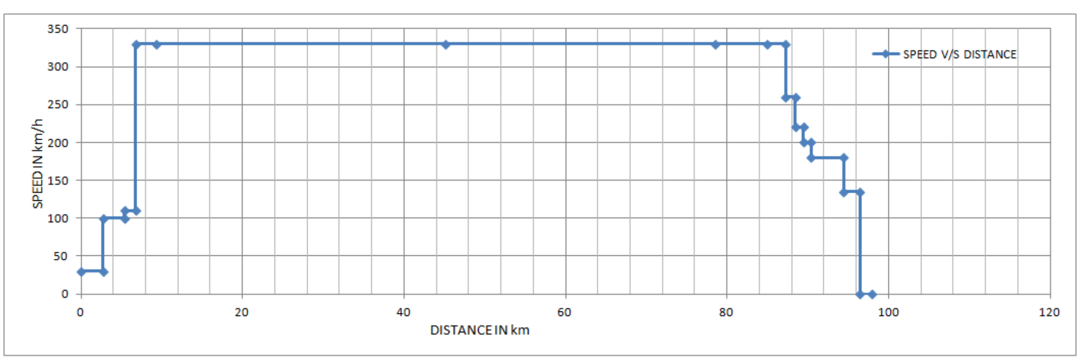
TABLE 6: COMPONENTS ETR1000 HIGH SPEED PASSENGER TRAIN

TRAIN	ETR 1000		
MAX SPEED (km/h)	300	330	360
Empty weight(Tare load) in Ton	454	454	454
With passenger weight (100%) in Ton	490	490	490
Maximum power (kW)	9800	9800	9800
Electric system	25kV 50 Hz	25 kV 50 Hz	25 kV 50 Hz
Formation	8 cars	8 cars	8 cars
Capacity	457 seats	457 seats	457 seats
Efficiency	90 %	90 %	90 %

RELATION OF SPEED V/S DISTANCE ACTUAL LIMIT:

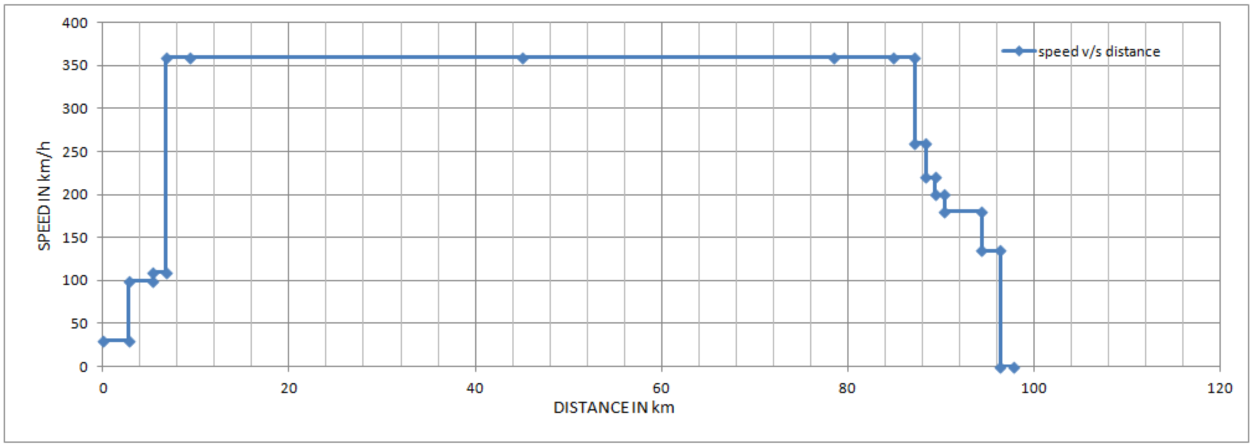
IN FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE HIGH SPEED LINE FOR FUTURE SCENARIO

We are shown graph 42 in below, relation between speed and distance with actual speed limit is 330km/h from FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE high speed line with distance is 96.484km.



Graph 42: Maximum Speed limit is 330 km/h, route from FIRENZE SANTA MARIA NOVELLA to BOLOGNA CENTRALE.

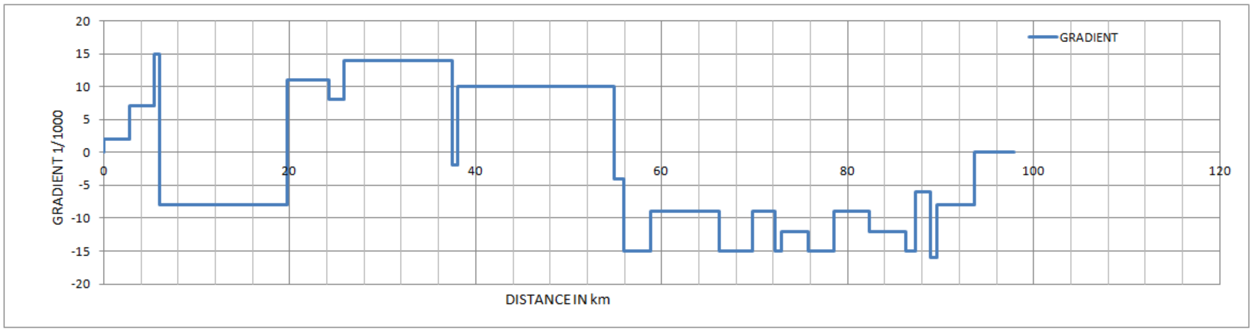
We are shown a graph 43 in below, relation between speed and distance with actual speed limit is 360km/h from FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE high speed line with distance is 96.484km.



Graph 43: Maximum Speed limit is 360 km/h, route from FIRENZE SANTA MARIA NOVELLA to BOLOGNA CENTRALE.

GRADIENT OF FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE:

We are shown graph 44 in below, relation between gradient and distance with actual speed limit is 360km/h from FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE high speed line and also maximum gradient is +15.00(1/1000) with distance is 96.484km



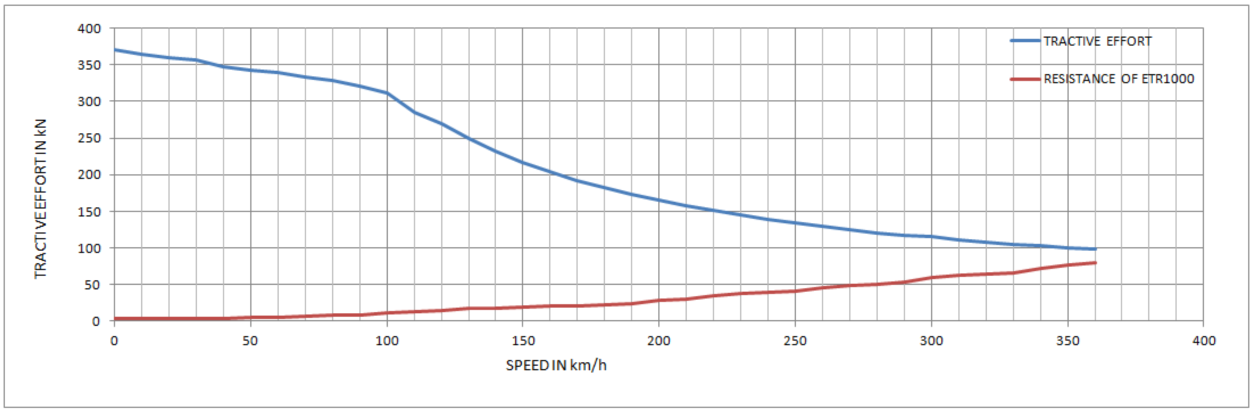
Graph 44: Surface of line FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE is shown in above figure

10.2 PERFORMANCE OF ETR1000 HIGH SPEED TRAIN

Some Analyse are done by using characteristics of ETR 1000 high speed passenger trains.

10.2.1 Tractive effort and Resistance:

- Tractive performance of ETR1000 of 25kV 50Hz and maximum tractive force is 370kN.
- RESISTANCE OF ETR1000 OF 25kV 50Hz and maximum resistance force is 60kN.



Graph 45: Tractive effort and Resistance

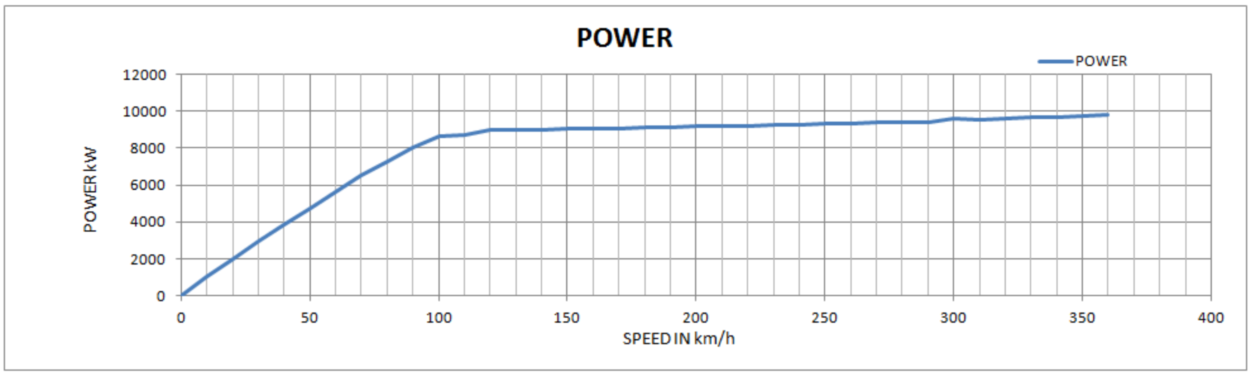
10.2.2 RELATION BETWEEN POWER AND SPEED:

From the below graph 46, we know the Maximum power of ETR 1000 High Speed Passenger Train is 9800 kW Consumed. And Speed varies at a time Power is varies.

From Theoretical Equation,

- Power = Tractive Force * Speed

$$P = T * V \qquad \text{[kW] or [W]}$$



Graph 46: Relation between Power and Speed

10.3 COMPARING 330km/h and 360km/h (WITH LIMIT SPEED)

10.3.1 RELATION OF SPEED V/S DISTANCE:

From the below graph 47, we know the performance with Speed and Distance.

a) SPEED V/S DISTANCE WITH ACTUAL LIMIT.
b) SPEED V/S DISTANCE 360 km/h WITH LIMIT.
c) SPEED V/S DISTANCE 330 km/h WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484 km.

- Actual Italy design speed, 360 km/h, and we operated maximum speed 360 km/h
- Actual Line design speed, 330 km/h, and we operated maximum speed 330 km/h in line Firenze Santa Maria Novella to Bologna Centrale.

We are comparing the speed with actual limits in two cases,

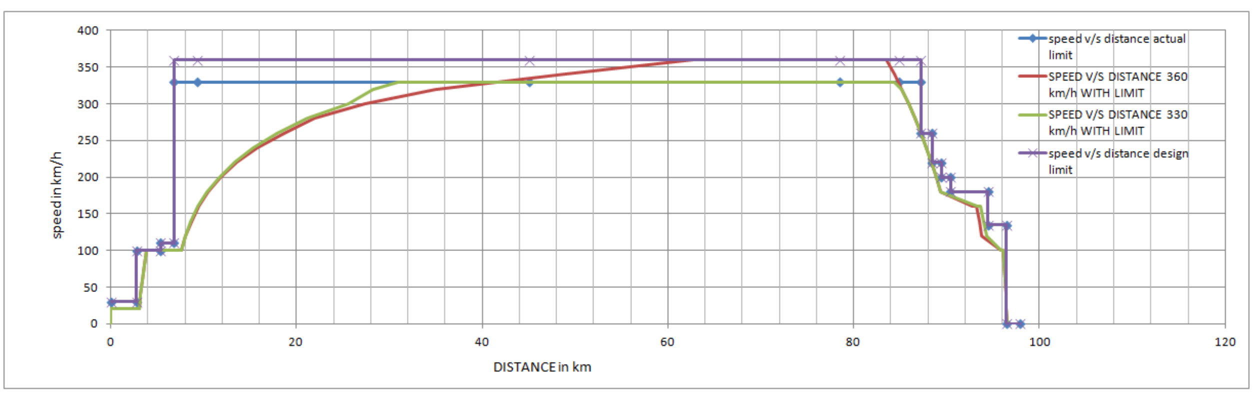
First case,

We done a process to know performance with Speed v/s Distance with limit speed for reach destination point with speed limit 360 km/h is actual limit. And its maximum speed in FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE high speed line.

Second cases,

We done a process to know performance with Speed v/s Distance With limit speed for reach destination point with speed limit 330 km/h is actual limit. And its maximum speed in FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE high speed line.

Comparing to know performance of speed in line:



Graph 47: Relation with Speed v/s Distance

10.3.2 REALTION 0F SPEED V/S TIME:

From the below graph 48, we know the performance with Speed and Time.

a) SPEED V/S TIME 360 km/h WITH LIMIT.
b) SPEED V/S TIME 330 km/h WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km.

- Actual Italy design speed, 360 km/h, and we operated maximum speed 360 km/h.
- Actual Line design speed, 330 km/h, and we operated maximum speed 330 km/h in line Firenze Santa Maria Novella to Bologna Centrale.

We are comparing the speed with actual limits in two cases,

First case,

We done a process to know performance with Speed v/s Time with limit speed for reach destination point with speed limit 360 km/h is actual limit. And its maximum speed in FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE line.

We consider as with limit speed for reach destination point

- Time taken is **1914 seconds / 31 minutes 45seconds**

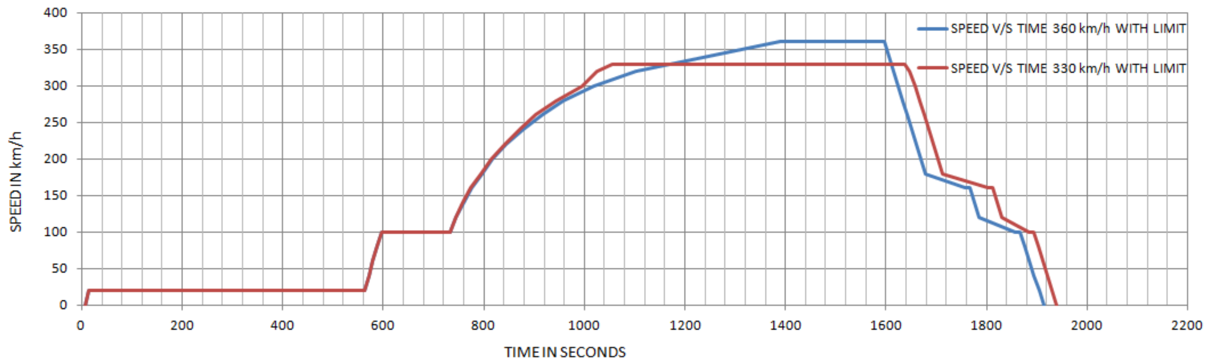
Second case,

We done a process performance with Speed v/s Time with limit speed for reach destination point with speed limit 330 km/h is actual limit. And its maximum speed in FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE line.

We consider as with limit speed for reach destination point (Bologna Centrale station):

- Time taken is **1940 seconds / 32 minutes 30 seconds**

Finally, we comparing graph 48 to know performance of speed and Time.



Graph 48: Relation with Speed v/s Time

10.3.3 <u>REALTION OF DISTANCE V/S TIME:</u>

From the below graph 49, we know the relation between Distance and Time.

a) DISTANCE V/S TIME 360 km/h WITH LIMIT.
b) DISTANCE V/S TIME 330 km/h WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km.

- Actual Italy design speed, 360 km/h, and we operated maximum speed 360 km/h.
- Actual Line design speed, 330 km/h, and we operated maximum speed 330 km/h in line Firenze Santa Maria Novella to Bologna Centrale.

<u>We are comparing the speed with actual limits in two cases:</u>

<u>First case</u>,

We done a process to know performance with Distance v/s Time with limit speed for reach destination point with speed limit 360 km/h is actual limit. And its maximum speed in FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE line.

We consider as with limit speed for reach destination point

- Time taken is **1914 seconds / 31 minutes 45seconds**

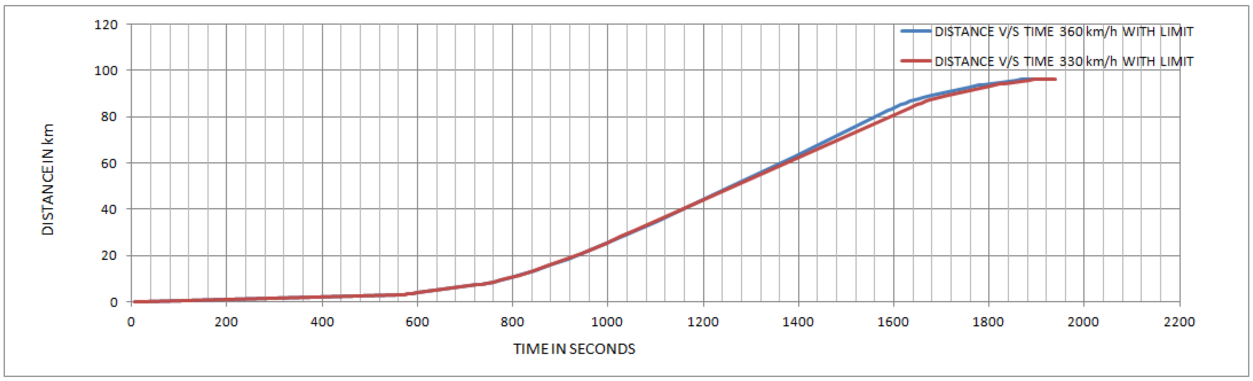
Second case,

We done a process to know performance with Distance v/s Time with limit speed for reach destination point with speed limit 330 km/h is actual limit and its maximum speed in FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE line.

We consider as with limit speed for reach destination point

- Time taken is **1940 seconds / 32 minutes 30 seconds**

Finally, we comparing graph 49 to know performance of speed and Time.



Graph 49: Relation with Distance v/s Time

RELATION OF ACCELERATION V/S DISTANCE:

From the below graph 50, we know the performance of Acceleration and Distance.

a) ACCELERATION V/S DISTANCE 360 km/h WITH LIMIT.
b) ACCELERATION V/S DISTANCE 330 km/h WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km.

- Actual Italy design speed, 360 km/h, and we operated maximum speed 360 km/h.
- Actual Line design speed, 330 km/h, and we operated maximum speed 330 km/h in line Firenze Santa Maria Novella to Bologna Centrale.

We comparing the acceleration with actual limits in speed of 330km/h and 360km/h

From theory,

Acceleration = Force / mass

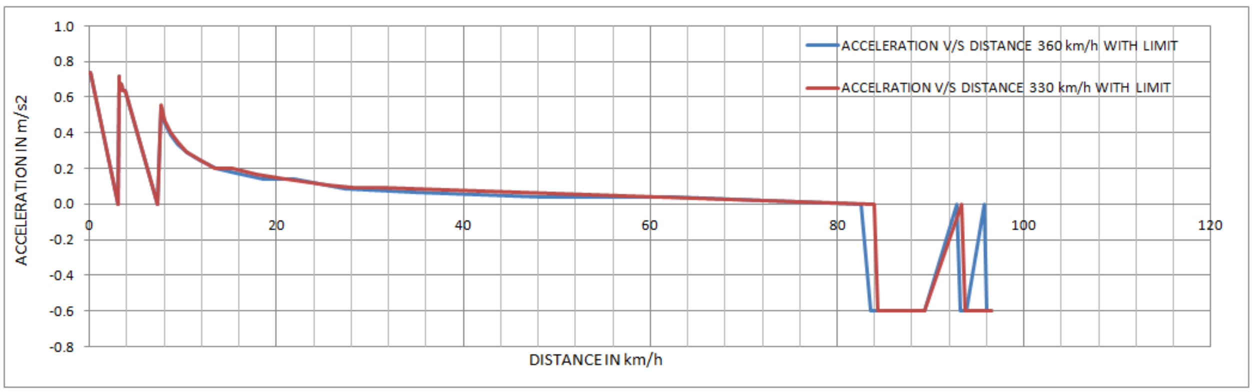
- ✓ $a = \frac{F}{M}$ [m/s2]

Δt = mass * speed / Traction force-Resistance force

- ✓ $\Delta t = \frac{M\,\Delta v}{T(vm) - R(vm)}$ [s]

- Max Acceleration = 0.739 m/s2
- constant de-acceleration = 0.6 m/s2

Finally, we comparing graph 50 to know performance of Acceleration and Distance.



Graph 50: Relation of Acceleration and Distance

RELATION OF ACCELERATION V/S TIME:

From the below graph 51, we know the performance of Acceleration and Time.

a) ACCELERATION V/S TIME 360 km/h WITH LIMIT.
b) ACCELERATION V/S TIME 330 km/h WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km.

- Actual Italy design speed, 360 km/h, and we operated maximum speed 360 km/h.
- Actual Line design speed, 330 km/h, and we operated maximum speed 330 km/hin line Firenze Santa Maria Novella to Bologna Centrale.

We comparing the acceleration with actual limits in speed 330km/h and 360km/h,

From theory,

Acceleration = Force / mass

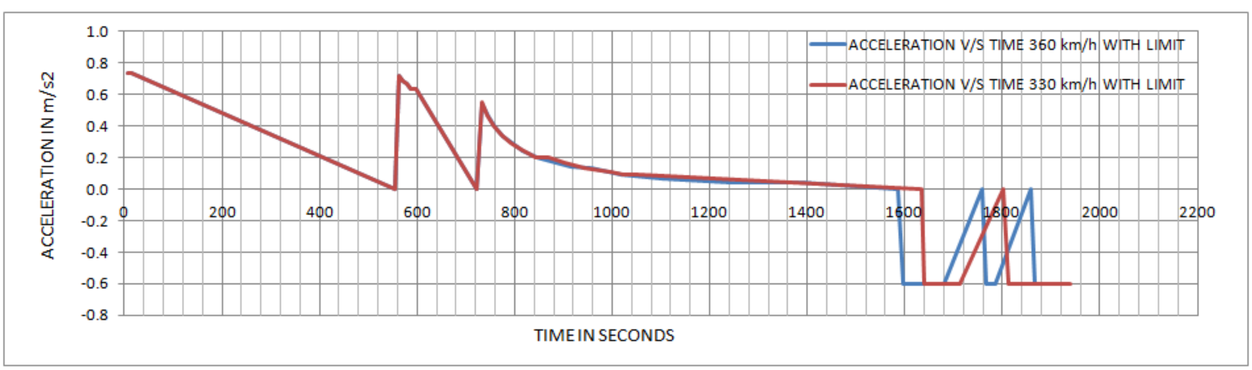
- ✓ $a = \frac{F}{M}$ [m/s2]

Δt = mass * speed / Traction force-Resistance force

- ✓ $\Delta t = \frac{M\,\Delta v}{T(vm) - R(vm)}$ [s]

- Max Acceleration = 0.739 m/s2
- And constant de-acceleration = 0.6 m/s2.

Finally, we comparing graph 51 to know performance of Acceleration and Time.



Graph 51: Relation of Acceleration and Time

10.3.4 RELATION OF ENERGY CONSUMPTION INPUT V/S DISTANCE:

From the below graph 52, we know Energy Consumption Input and Distance.

a) ENERGY CONSUMPTION INPUT V/S DISTANCE 360 km/h WITH LIMIT.
b) ENERGY CONSUMPTION INPUT V/S DISTANCE 330 km/h WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 330km/h, Distance is 96.484 km

From theory of Equation,

Energy output or wheel = energy input * efficiency

- ✓ $E\ output = E\ input * \eta$ [kW-h]

We comparing the energy consumption input with actual limits in two cases,

- Actual Italy design speed, 360 km/h, and we operated maximum speed 360 km/h.
- Actual Line design speed, 330 km/h, and we operated maximum speed 330 kM/h in line Firenze Santa Maria Novella to Bologna Centrale.

First cases,

We consider as with limit speed 360km/h for reach destination point Bologna Centrale

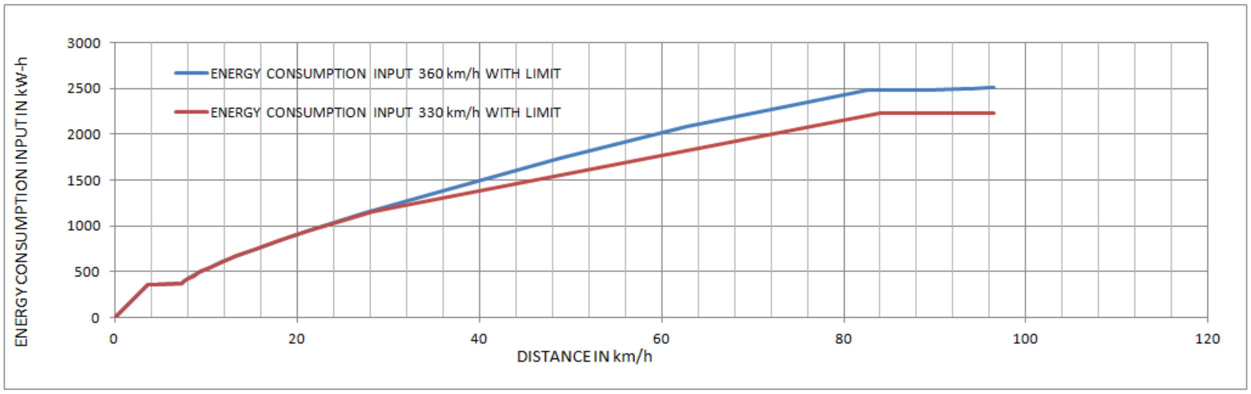
- Energy consumption input is consumed **2502** [kW-h]

Second cases,

With limit speed 330km/h for reach destination point is Bologna Centrale

- Energy consumption input is consumed **2232** [kW-h]

Finally, we comparing graph 52 to know performance of Energy Consumption Input v/s Distance and gradually increases.



Graph 52: RELATION of Energy Consumption Input v/s Distance

10.3.5 <u>RELATION OF ENERGY CONSUMPTION OUTPUT V/S DISTANCE:</u>

From the below graph 53, we know the Energy Consumption Output and Distance.

a) ENERGY CONSUMPTION OUTPUT V/S DISTANCE 360 km/h WITH LIMIT.
b) ENERGY CONSUMPTION OUTPUT V/S DISTANCE 330 km/h WITH LIMIT.

Distance of FIRENZE SANTA MARIA NOVELLA TO BOLOGNA CENTRALE High Speed Line is 96.484km and the maximum speed is 330km/h.

Assuming, Efficiency is 90 %

From theory of Equation,

Energy output or wheel = energy input * efficiency

✓ $E\ output = E\ input * \eta$ [kW-h]

We comparing the Energy Consumption output and Distance with actual limit,

- Actual Italy design speed, 360 km/h, and we operated maximum speed 360 km/h
- Actual Line design speed, 330 km/h, and we operated maximum speed 330 km/h in line Firenze Santa Maria Novella to Bologna Centrale.

We comparing the energy consumption output with actual limits in two cases,

<u>First cases,</u>

With limit speed 360km/h for reach destination point is Bologna Centrale

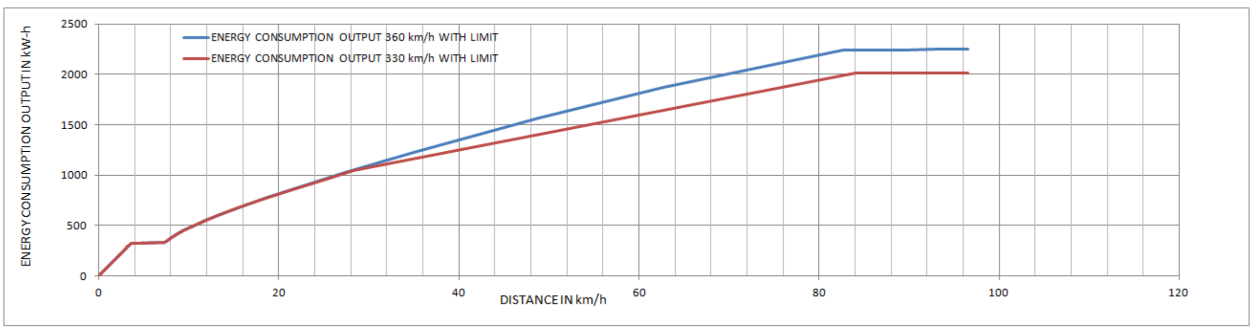
- ➢ Energy consumption output is consumed **2252** [kW-h]

<u>Second cases,</u>

We consider as with limit speed 330km/h for reach destination point Bologna Centrale

- ➢ Energy consumption output is consumed **2009** [kW-h]

Finally, we comparing graph 53 to know performance of Energy Consumption Output v/s Distance and gradually increases.



Graph 53: Relation of Energy Consumption Output v/s Distance

COMMERCIAL SPEED OF HIGH SPEED PASSENGER TRAINS

Equation of Commercial Speed (with limit speed) is

Vc = Distance of origin to destination / Total travelling time of origin to destination

$$Vc = \frac{L}{ta+tr+tf+ts}$$ [m/s] or [km/h]

- ❖ ETR1000 (with limit speed) = **179** [330km/h]
- ❖ ETR1000 (with limit speed) = **182** [360km/h]

As we shown below in tabular column:

From the below table 7 we showing a characteristics of high speed trains ETR1000 mainly on Speed, Distance, Time and Energy Consumption of input and output with limit speeds are 300km/h, 330km/h and 360km/h.

TABLE 7: Characteristics to know performance of high speed passenger train and energy consumption

TRAIN NAME	ETR1000		
	WITH LIMIT		
FIRENZE SMN TO BOLOGNA.C.LE			
MASS (Ton)	490	490	490
MAX LINE SPEED (km/h)	300	330	360
DISTANCE (km)	96.484	96.484	96.484
TIME (Seconds)	**2014**	**1940**	**1914**
COMMERCIAL SPEED (km/h)	172	179	182
ENERGY CONSUMED ENGINE (kW)	**1918**	**2232**	**2502**
ENERGY CONSUMED WHEEL (kW)	**1726**	**2009**	**2252**
POWER (kW)	9583	9671	9800

CHAPTER 11

CONCLUSION OF THESIS

CONCLUSION:

The route of high speed line from Firenze Santa Maria Novella to Bologna Centrale with characteristics of High Speed Passenger trains. We analysing the first step, 20km/h speed was assumed around distance 3km. But actual speed limit is 30km/h in distance between 3km to 5km. Performances shown with limit speed, we know the differences in performance.
And Distance is 96.484km/h and actual speed limit is 300km/h.

Types of trains considered for thesis are Distributed, Concentrated and two Loco & Trailer. We consider theoretical methodology to find performances of train. Mainly on Energy Consumption, Time, Commercial speed and Number of passenger

First we done a process of ETR1000 high speed train to know the performances of Train are Energy Consumption, Time, Commercial speed and Number of passenger without limit speed and with limit speed.

ETR1000 Comparing characteristics of High Speed Passenger Trains are ETR 500, ICE 3 Velaro E & TGV-THALYS to know Energy Consumption, Time, Commercial speed and Number of passenger with limit speed.

Analyse the reducing 10 % of actual mass weight with passenger of four high speed trains and 10 % of Number of passenger seats. 10% of weight reduced trains are ETR1000, ETR500, ICE 3 Velaro E & TGV-THALYS.

ETR1000 Comparing characteristics of High Speed Passenger Trains are ETR 500, ICE 3 Velaro E & TGV-THALYS to know Energy Consumption, Time, Commercial speed and Number of passenger with limit speed.

Main objective of thesis are first case, if passengers are less than Energy will be consumed less and second case, if passengers are high than Energy will be consumed more.

We as done a future scenario for ETR1000 high speed train and the route of high speed line from Firenze Santa Maria Novella to Bologna Centrale with characteristics of High Speed Passenger trains. Distance is 96.484km/h and future scenario speed limit is 330km/h and 360km/h.

Future operation: actual speed limit is 300 km/h but, we implement the design line speed to 330 km/h in FIRENZE SANTA MARIA NOVELLA to BOLOGNA CENTRALE LINE. To know performance of ETR 1000 high speed passenger train in 330 km/h are Energy Consumption, Time, Commercial speed and Number of passenger with limit speed.

Future operation: actual speed limit is 300 km/h but, we implement the Italy design speed to 360 km/h in FIRENZE SANTA MARIA NOVELLA to BOLOGNA CENTRALE LINE. To know performance of ETR 1000 high speed passenger train in 360 km/h are Energy Consumption, Time, Commercial speed and Number of passenger with limit speed.

And we comparing all performances of ETR1000 high speed passenger train with limit speed 330km/h and 360km/h are Energy Consumption, Time, Commercial speed and Number of passenger with limit speed.

Today in Italy no limitation and/or recommendation for energy consumption, for sure in near future additional cost for energy consumption will be implemented.

Comparing ETR1000 and WAP 5 LOCOMOTIVE:

When we comparing India and Italy Locomotive, the gauge 1435 mm and

1676 mm is different standard between each other and also Maximum Speed in India is 160km/h. This information is not considered in thesis.

UNITS:

- Speed = [km/h] or [m/s]
- Forces = [kN] or [N]
- Acceleration = [m/s2]
- Time = [hour] or [min] or [s]
- Distance = [km] or [m]
- Energy consumption = [kW-h]
- Power = [kW]
- Work = [kN-m] or [kJ]
- Commercial speed = [km/h]

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[14]: http://web.tiscali.it/lcartello/misc/RFI-Elenco%20fascicoli%20linea.xls In this link, we analysed maximum speed of line in route of Santa Maria Novella to Bologna Centrale line.

[15]: http://web.tiscali.it/lcartello/misc/RFI-Elenco%20fascicoli%20linea.xls In this link, we analysed maximum gradient of line in route of Santa Maria Novella to Bologna Centrale line.

[16]: http://www.cifi.it/UplDocumenti/AV_Freccia1000/BOMBARDIER%20ETR1000.pdf Components of ETR1000 High Speed Passenger Train are have in this link.

[17]: https://www.google.com/imgres?imgurl=http%3A%2F%2Fwww.railway-technical.com%2F_Media%2Fbogiept_med_hr_med_hr.jpeg&imgrefurl=http%3A%2F%2Fwww.railway-technical.com%2Ftrains%2Frolling-stock-index-l%2Fbogies.html&docid=DpowSp9teSLZnM&tbnid=werB6NMqxBUWPM%3A&vet=10ahUKEwitvM_e5__fAhUHzqQKHWj-CXIQMwg_KAAwAA..i&w=825&h=384&bih=657&biw=1366&q=bogiept_med_hr_med_hr&ved=0ahUKEwitvM_e5__fAhUHzqQKHWj-CXIQMwg_KAAwAA&iact=mrc&uact=8 Image have in this link.

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External links:

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