Enhanced Capacity Sleeper Coach

A 600mm increase in internal height of coach without increasing the permissible overall height, allows 4-tier accommodation in passenger sleeper stock. This has strong effects on energy efficiency, life cycle costs, meeting the demand in overnight trains and select busy routes.

Technology field: Space utilisation

1 General information

2 Description

1.1. Principle

Conventional stock for long-distance and regional service has an exterior coach width of around 3245mm and a height of 4025mm with internal layout of 3+3+2 per bay multiplied by 9 bays accommodates 72 berths. In an effort to increase passenger accommodation per coach, trains could be developed that are comparatively spacious on the inside. For our purposes, we define a 4tier sleeper coach as one allowing 4 + 4 berths in the transverse arrangement and 3 berths in the longitudinal arrangement per bay in Non Air-conditioned sleeper. The gain in a 4tier coach version indicates an increase in capacity of 38%compared to the "enhanced" version and 52% compared to the “standard” version.

Examples

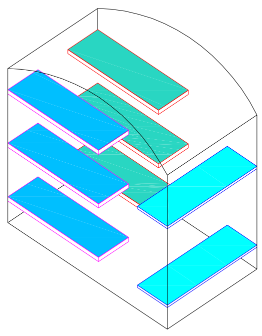
The following table lists some of the variation in body height, width & “Maximum Moving Dimentions” (MMD)/Structural Gauge of Indian Railway, 1676mm gauge trains.

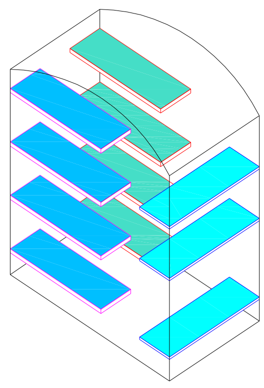
Type of Coach	**Height from Rail**	**Max. Width above Platform**	**Length**	**Berth Layout & Accommodation**	**MMD Ref. No.**
Standard 3-TIER Sleeper CSC-1705 (ICF/RCF)	4025mm	3245mm	22.297 m	3+3+2*9=**72** **(72 berths)**	SK-66064
Enhanced 3-TIER Sleeper CSC-1744 (BEML)	4025mm	3250mm	22.297 m	3+3+3*9=**81** **(81 berths)**	SK-66064
Enhanced 3-TIER Sleeper CSC-1759 (ICF/RCF) Modified Eurofima by LHB	4039mm	3240mm	24.000 m	3+3+2*10=**80** **(80 berths)**	SK-66064
Enhanced Sleeper CSC-1749 (BEML)	4025mm	3250mm	22.297 m	3+3+3*9=81+3=**84** **(84 berths)**	SK-66064
Enhanced 3-TIER Sleeper CSC-1737 (ICF/RCF)	4381mm	3250mm	22.297 m	3+3+3*9=81+3=**84** **(84 berths**	Modified SK-66064 2005/CEDO/SD/9
Air-Con 3-TIER Sleeper CSC-1731 (ICF/RCF)	4250mm	3245mm	22.297 m	3+3+3*8=**72** **(72 berths)**	SK-72227
Air-Con Garib Rath Sleeper	4250mm	3245mm	22.297		Modified SK-66064

CSC-1731 (ICF/RCF)			m	(74 berths)	

Source: Research, Designs and Standards, Organisation of Indian Railways

- Indian Railway is probably among the few railways of densely populated countries that has such a crammed 3-tier sleeper coach layout.
- The demographic trends demand ever increasing capacity in sleeper class coach.
- Such an arrangement compromises comfort level to some extent to accommodate a larger population.
- Attempts to enhance sleeper capacity have been made in the past as is evident by adding a third berth on the longitudinal layout.
- Since the third berth in the longitudinal layout was found to be claustrophobic, the overall coach height was increased from 4025mm to 4381mm, to reduce this inconvenience by increasing the floor to ceiling height from 2622mm (approx) to 2966mm (approx).





Standard 3-TIER Sleeper

Enhanced 4-TIER Sleeper

3 General criteria

Status of development:

2.1 Various attempts have been made to resolve the energy efficiencies, space utilization, line capacity and the growing passenger demand in India.

2.2 Time horizon for broad application: 10-15 years

- Policy Decision: 6 months - 1 year
- Technical Design: 1 – 2 years
- Prototyping: 1 year
- Trial and Feedback: 1 – 2 years
- Series Production (before impact on fleet): 10 years

2.3 Expected technological development:

2.3.1. Infrastructural compatibility

As opposed to isolated solutions, mainline service sets rigorous conditions to “Maximum Moving Dimentions” (MMD) on proposed rolling stock, especially if nation-wide operability is demanded.

However survey of infrastructural compatibility to higher MMD rolling-stock may reveal that it is possible to run these trains on several routes and corridors by removing or modifying minor infringements.

Further, it is highly desirable to develop standardized advanced methods for vehicle gauging, based on simulations, thus making it possible to fully utilise the available structural gauge.

2.3.2. Comfort

More research and development is needed to better understand the relations between used space, experienced space, ergonomic factors and passenger’s positive / negative feelings, their choice of berth as well as willingness to travel in the proposed layout. It is also desirable to develop trains with even higher comfort in the long term. It is then favorable to increase interior width .In such a case it is important to introduce new wall designs with reduced thickness (and maintain strength).

4 Motivation:

3.1. Capacity

Capacity considerations are the main motivation for using 4-tier sleeper coach: Increase the number of passengers per train on saturated lines/corridors/sections. This means that 4-tier sleeper stock increases capacity by around 38% or more.

3. Benefits (other than environmental):

4.1..Compared to normal trains:

- Capacity: Increased capacity of a line. Increased platform capacity.

- Lower floor height: Easier embarkation and disembarkation.
- Night train comfort: The 4-tier is ideally suited to over-night journeys.
- Long distance journeys: Permits more passengers to lounge on the fixed berths during the day.
- Tilting: lower centre of gravity, possible car-body tilt and higher curving speeds,
- Since platform length of many stations is limited, large MMD rolling stock is a means to increase the capacity of a line without increasing train frequency or investing into the construction of new infrastructure.

4.2. Compared to double-decked Regional day journey trains, typically 136 seats/coach :

- Capacity: sitting=110, lounging= 60, total=170. Additional capacity 25%.
- Revenue: Berth accommodation brings in higher revenue than seat.
- Equipment: Most of the equipment can be accommodated in the available under floor space of the coach, typically 20 – 25 m^3.
- Catering: level floor within the train making it possible to arrange ambulant catering service
- Simplicity: simpler construction.

5. Barriers:

5.1. Acceptance by the Ministry for Railways and Zonal/Regional managements

From the view of the Indian Railway Board, a great obstacle is given by the paradigm of many officers to accept only stock that can in principle be used throughout the network. This impedes insular solutions for regional and isolated networks allowing large MMD stock where ever possible. There is precedence of operating Double-decker intercity and Garib Rath trains on select routes, and similarly it is possible to introduce these coaches where ever passenger demand justifies and structural gauge permits.

5.2. Infrastructure

The main obstacle for the introduction of large MMD stock lies in the infrastructure, which is not adapted to optimum MMD of rolling stock for 1676mm gauge, for historical reasons. For certain isolated networks, some regional and long distance lines the proposed rolling stock could be introduced without major infrastructural changes. The demand for interoperability on routes with permanent structural limitations i.e. tunnels, bridges, ROBs, etc. and high speed traffic limits the proposed stock considerably. This can be exemplified by the Garib Rath which is permitted only on select routes.

5.3. Passenger acceptance of 4+4+3-tier arrangement per bay

A 4+4+3 berth solution may result in a certain reduction of passenger comfort.

5.3.1. The 3-seat in the longitudinal (side) arrangement may be considered uncomfortable and may not be readily accepted by passengers.

A. It has been observed that majority of travelling public on the Indian Railways do not lift the fold-down backrest during the day to use the seat like a chair. They have to share the berth between 3 persons, (1 reserved & 2 Wait-Listed).
B. Since the fold-down berth is kept in the lounging position throughout the journey for sitting during the day and sleeping during the night, the same is proposed to be a fixed type cushioned bench/berth like the other lower berths of the coach. This arrangement will also permit unhindered space for luggage.
C. To overcome the grievances of uncomfortable back rest while occupied by three passengers, it is proposed to use padded panels on three sides of the lower berth to enhance the level of comfort during sitting.

5.3.2. The 3-berth in the longitudinal (side) arrangement may be considered uncomfortable and may not be readily accepted by passengers due to uncomfortable experience from previous attempts on the Indian Railways.

The principal public grievance against the earlier designs was claustrophobia.

A. The present arrangement addresses the objections and proposes a layout which is in fact similar to the space provided for the side lower berth of the present day regular 3-tier coach design, to permit acceptable headroom to sit comfortably without folding the middle berth.
B. The middle berth has been provided in the additional internal dimensions and by scavenging every millimeter of space that could be re-adjusted to meet the minimum 610mm headroom required.
C. The upper berth headroom would permit short period sitting in typical *"Sukhasana"* Indian style for eating and other necessities as enjoyed presently in the regular coach design.
D. Additional windows are planned for the upper and middle berths to meet the ventilation, light and visual needs.

5.3.3. The upper berth of the 4-tier during summer may be considered uncomfortable.

A. The upper berth headroom is in fact similar to the upper berth of the present 3-tier design which permits short period sitting in typical *"Sukhasana"* Indian style for eating and other necessities as enjoyed presently in the regular coach design. Therefore the radiating heat through the ceiling is not going to be felt anymore than now. The problem can be abated with a superior insulation material that meets the other criteria such as 'fire retardant' etc.

5.3.4. The feeling of acrophobia (irrational fear of height) may be a problem with a small percentage of the population.

A. The reservation software can be programmed to allot the 4th berth to a select age group of male passengers. Mentally challenged passengers, suffering from this phobia could be allotted lower berths.

5.3.5. However survey of passenger acceptance and preference need to be undertaken to arrive at any conclusions

A. Expressed as willingness-to-pay for more comfort in 3-tier coach on popular trains.
B. Expressed as willingness to accept 4-tier accommodation, 4+4+3-arrangement per bay.
C. Expressed as willingness-to-pay differential fare structure for comfort level of 4+4+3-arrangement:
   a) Lower berth
   b) Lower middle berth
   c) Upper middle berth
   d) Upper berth
   e) Lower side berth
   f) Middle side berth
   g) Upper side berth

D. Expressed as need for:
   a) Urinals for male passengers
   b) Pay and use toilets
   c) Automatic seat retracting western(sitting type) toilet
   d) Number of toilets per 4-tier coach

5.4 . Technological shortcomings

5.4.1. Bogie

Bogie with small diameter wheel for mainline trailer coach needs to be designed and tested.

5.4.2. . Coach shell and furnishing

Coach Shell and furnishings also need to be designed and tested for the following parameters:

- Weight reduction
- Fenestration & water proof ventilation
- Thermal insulation
- Provision for air-conditioning
- Toilet and male urinal layout
- Emergency exit / escape
- Crash worthy & anti-telescopic properties
- Energy efficient lighting & air circulation
- Noise reduction
- Efficient space utilization

5 Success factors:

5.1 Individual:

Conviction of the CEO of the Railways can see the implementation of this Technology in a short time frame.

5.2 Assessment of potential for insular solutions

An unbiased assessment of the operability of large MMD stock on parts of the infrastructure will mostly reveal major potential in local and regional operation. If a small number of obstacles have to be removed, a cost-benefit analysis has to evaluate the profitability of such a transition.

5.3 Critical revision of the paradigm of “national interoperability”

Many railway operators only prefer stock with a high degree of applicability throughout their infrastructure. For example, a mainline Garib Rath coach used on the Dehli-Jaipur route to be usable in other parts of the country as well. This obviously limits the potential for large MMD stock. A critical revision of this “national interoperability” paradigm is needed to assess whether it is economically reasonable.
a variety of internal and external issues will also influence, such as:

- Policy and economic framework (market deregulation, energy prices etc.)
- Developments in relevant mass markets
- R&D efforts in industry and railways including feasibility studies
- Dependence on other technological or strategic decisions within railways or Original Equipment Manufacturers
- Communication policy to improve acceptance

Applicability for railway segments:

Type of traction: electric - DC, electric - AC, diesel

Type of transportation: passenger - main lines, passenger - regional lines.

High potential in isolated networks, such as saturated routes which can permit large MMD.
On main lines, potential may be much greater than commonly assumed:
In 1990 DB, DSB and NS concluded that stock of a max. width of 3200 mm at around 1600 mm above rail level and of normal width at platform and roof level could in principle be accommodated on these three systems.
A Swedish study concluded that it would be possible to accommodate a car-body width of 3.4 -3.5 m at “elbow height”, within the present structural gauges in Sweden and Norway, likely also in Denmark.
Studies by DB AG indicate that the main part of the ICE network with the exception of very few bottlenecks can be worked by trains 3.40 m wide. Concepts excluding narrow sections could be feasible in mid-term perspective on the major network axes.
Research by Swedish KTH showed that wide-body trains can be used on many markets, not only high-speed, InterRegio, local and regional trains but also for day-and-night trains. To make night-trains profitable in the future it is necessary to design trains that can be used both in night-service and in day-service.

Grade of diffusion into railway markets:

Diffusion into relevant segment of fleet: >15%

Share of newly purchased stock: < 20%

(no details available)

Market potential (railways):

(no details available)

Example:

For the new enhanced capacity sleeper coach for the mainline, RDSO needs to developed in collaboration with the innovative talent. One of the means to achieve this is competition as mentioned above.
Chinese high speed train technology developed indigenously and series production begun within five years.
In order to increase seats per train length and reduce energy consumption per seat, the car-body was extended to the outer limits allowed by track profile and station platforms. A car-body height of 4.36m proved feasible (0.11m more than the old stock). This allowed three extra berths per bay i.e. 4+4+3 multiplied by 10 bays is = 110 (old: 3+3+2 per bay multiplied by 9 bays is = 72). This along with a number of other measures reduced weight per berth estimated at 27 % to 418 kg. Compared to previously used stock, energy consumption will probably reduce by approximately 25% on passenger basis.

Environmental criteria

Impacts on energy efficiency:

Energy efficiency potential for single vehicle: > 20%

Energy efficiency potential throughout fleet: > 5%

In order to estimate the reduction of seat-specific energy consumption, conventional (3 tier sleeper) and enhanced (4 tier sleeper) versions of an otherwise identical train (e.g. equal length etc) are compared.
Aerodynamic effect of wider coach
The cross-section of the coach shell is increased by ~10%. Although air resistance grows with cross-sectional area in a less than proportional way, it is safe to assume that air resistance grows in the order of 5% or less, for the shell; the bogie cross-sectional area is reduced resulting insignificant aerodynamic resistance.

Mass effect of wider coach
The design study for an enhanced sleeper coach yielded a mass increment of about < 20% in comparison to conventional standard sleeper coach.
Comfort functions
Insignificant effect on the energy consumption is anticipated for non air conditioned enhanced sleeper coach.
No data are available on the effect on the energy consumption of comfort functions in an air conditioned enhanced sleeper coach.
For obvious reasons (less wall surface per seat, less interior space to be heated per seat etc), it is increased by less than the relative increase in seating capacity. 10% will be a safe upper limit here as well.

Energy consumption of the entire train
Since all components of energy consumption of a passenger train (mass, air drag and comfort energy) are increased by about 10% (or less), the energy consumption will also increase by 10% or less.
Seat-specific energy demand
Since seating capacity is increased by about 38%, the 110% energy consumption have to be divided by 1.38 to get the seat-specific energy demand relative to a conventional coach design. The result is a reduction of seat-specific energy consumption by 21%.
Assuming that a maximum of half of the regional lines and some of the main lines could be operated with enhanced sleeper coach in long term, the applicability in most fleets will not exceed 25%, but could reach values of up to 40% in some fleets. Accordingly, this gives a maximum system-wide effect of 2 - 5 %.

Other environmental impacts:

(no details available)

Economic criteria

Vehicle - fix costs:

(No details available)

Vehicle - running costs:

Maintenance costs: an increase of 5% per coach per annum while it will decrease by 24% per berth.
Energy costs per seat: 20% reduction

Infrastructure - fix costs:

No infrastructure investment is anticipated in several routes. Only minor adjustments in existing infrastructure are maybe required in some corridors. Considerable investment in additional infrastructure is anticipated for some sections (tunnels, bridges, etc) may restrict the structural gauge where introduction of these enhanced coaches will not be economically justified.

Infrastructure - running costs:
(no details available)

Scale effects:

Standardisation of components and larger series production is indispensible in Indian railway scenario to meet the growing demand of sleeper class coaches.

Amortisation: 1-2 years

Highly dependent on routes requiring unchanged infrastructure.
Life-cycle costs (LCC) can be cut by up to 12 % per seat.
Cost savings of operating enhanced sleeper coaches is so high that, even if the full costs of removing bottlenecks on selected routes are charged to the programme, there will still be cost savings.

Application outside railway sector (this technology is railway specific)

Overall rating

Overall potential:

Time horizon:

Focusing on rolling stock only, enhanced sleeper coach is the most promising design option as far as space utilisation for overnight and intercity day trains are concerned. Design studies show strong seat/berth-specific advantages with respect to energy efficiency as well as both investment and operation costs. Technological barriers are low and infrastructure problems are usually limited to isolated points of the network. Interoperability limited to routes without infringement. For mainline operation the demand for enhanced coaches is high considering the demographic and travel trends in India. There is urgency for the required technology and prototyping to meet the existing demand.