

# Development of the railway vehicles axle assemble

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## 1 Introduction

Considering the historic development of railway vehicles one can see that the first vehicles were double-axle (Figure 1a). The need to increase the loading capacity of the vehicles created a need to increase its length. This also meant an increase of the wheel base. Double-axle vehicles with a greater wheel base had problems in negotiating curves because of the greater angle of contact of the wheels on the outer track. A partial solution for increasing the length of the vehicle meant an increase of the vehicle superstructure overhang compared to the axles (Figure 1b). This, however, increased the moments acting as a load on the box.

Apart from problems in negotiating curves, double-axle vehicles drove in an unsteady manner along straight lines and at higher speeds, due to the excitation caused by the winding movement of the wheel and axle sets.

The invention of the bogie was a perfect solution. Vehicles with bogies showed a steady movement along straight lines and a significantly easier driving round the curves. Vehicles with bogies could be even longer and could have greater loading capacity. (Figure 1c). Thus, the bogies have up to the present remained the basic form of axle assemble (driving unit) of all railway vehicles.

If this work analyses only passenger railway cars, it is obvious that the cars with bogies have become very long, narrow and with a great proper mass. It should be noted that a significant portion in the overall vehicle mass have the bogies. This portion is between 25 and 35%.

Considering that apart from the resistance to air, all other resistance to the motion of the train depend on its

*L'articolo presenta una rassegna sull'evoluzione tecnologica dei gruppi d'assi (unità di guida) dei veicoli ferroviari, unitamente ad un'analisi della situazione corrente e delle possibilità di futuri sviluppi. L'analisi prende come riferimento le esigenze che i moderni veicoli ferroviari devono soddisfare al fine di trovare soluzioni che vadano incontro a tali esigenze per quanto riguarda il particolare aspetto delle unità di guida. La principale richiesta nell'evoluzione dei veicoli ferroviari è la riduzione della massa lorda. Oggi nelle carrozze passeggeri più di un terzo della massa è imputabile ai carrelli; una possibile soluzione per ridurre la massa totale dei veicoli dovrebbe indirizzarsi verso veicoli a due assi. I problemi che palesano i veicoli a due assi nell'affrontare la curva potrebbero essere risolti con l'imperniaggio mobile degli assi in una posizione radiale, utilizzando opportuni meccanismi. I primi test di veicoli a doppio asse hanno mostrato risultati soddisfacenti riguardo alla riduzione della massa totale delle carrozze, alla possibilità di un più agevole scorrimento lungo i tratti curvilinei e all'uniformità del moto nei tratti rettilinei di binario.*

mass, it is important for the reduction in energy consumption in railway traction to make the vehicles as light as possible. The lightness in construction has therefore become the imperative of the modern vehicles. In order to reduce the proper mass of the vehicles, there are significant possibilities in the variation of the driving unit, i.e. reduction of its mass. One of these possibilities is the double-axle vehicle design.

## 2 Analysis of the possible axle assemble solutions

Today's vehicles are very long and with bogies (Figure 2a). By increasing the length, the width of the vehicle has to be reduced so as to maintain the vehicle, when negotiating a curve, within the structure gauge (Figure 2b). Therefore long vehicles do not utilise the structure gauge in a satisfactory way, since narrow vehicles carry fewer seats in a single row compared to shorter but wider vehicles.

The underframe with the vehicle body presents a beam continuously sub-

jected to the bending load with supports at the swivelling units of the bogies (Figure 2c). The deflection  $f$  of such a beam depends on the length to the power of four ( $f = \text{const.} \cdot ql^4/EI$ ). In order to keep the deflection within allowed limits the moment of inertia  $I$  has to increase along with the increase of the vehicle length, which also means the increase in the vehicle weight. Therefore, long vehicles are at the same time heavy vehicles.

Looking at the ends of two connected four-axle cars with bogies, one has to notice that a small space accommodates as many as four axles, i.e. two bogies (Figure 2d). This means insufficiently utilised axles, heavy weight and an expensive solution.