New Generation of SKODA Trams in European Cities

Actual tramcars products

Jiří Vokoun – Tram platform product manager
New Generation of SKODA Trams in European Cities

Content of presentation:

- Trams conception overview
- Trams sales in Europe in 2009 – 2014

- Selection of the optimal vehicle – Technical requirements – cities differences – difference of specific marginal conditions
- Economical aspects – transport costs minimization (LCC)
- Influence of vehicle producer on LCC – vehicle conception and solution, reliability, energy losses, recuperation, …

- ForCity family overview – vehicle conception, bogie generations
- ForCity projects overview
- ForCity products presentation – reference vehicles, standard vehicle conceptions, customized conceptions
Škoda Transportation – Trams products

Actual market overview (conceptions) – ST product range
Trams sales in 2009 - 2014

Bogie - pivot vs rigid (2009-2014, Germany)

Bogie - pivot vs rigid (2009-2014, Europe)

Bogie - pivot vs rigid (2009-2014, Sweden)

Wheel set design (2009-2014, Europe)

1 – axle; 2 - axlebridge

Parameters that define or prompt about sold vehicle concept
Technical requirements – main cities differences (specifics)

<table>
<thead>
<tr>
<th>Vehicle parameters</th>
<th>Main city limitations and conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle conception ?</td>
<td>Tracks specification, frequency of curves, historical practice, …</td>
</tr>
<tr>
<td>Vehicle dimensions – length, width, cross-section shape, …</td>
<td>Length of platforms, position of the platform, infrastructure limitations, number of doors, % of LF, slopes, …</td>
</tr>
<tr>
<td>Vehicle weights – total weight, axle loading,</td>
<td>Maximal tracks loading, tracks and wheel wearing minimization, balanced axles loadings, …</td>
</tr>
<tr>
<td>Vehicle capacity – capacity maximization, …</td>
<td>Transport capacity, vehicle capacity, number of seats, seats accessibility, passengers/entrance stream, …</td>
</tr>
<tr>
<td>Vehicle envelope limitations – conception and dimensions</td>
<td>Infrastructure limitations, depot limitations, old vehicles passing, …</td>
</tr>
<tr>
<td>Vehicle performance parameters – power, adhesion ratio, …</td>
<td>Weather conditions, slopes, sufficient accelerations, …</td>
</tr>
<tr>
<td>Vehicle power supply – additional battery power pack</td>
<td>Supply voltage and current, effectiveness of recuperation, …</td>
</tr>
<tr>
<td>Specification, special features, special solutions</td>
<td>Compatibility with old vehicles, way of fare collection, …</td>
</tr>
</tbody>
</table>

Many operators requirements need more vehicle conceptions and many vehicle specification = necessity of the universal vehicle platform
Optimal solution x Historical limitations x Investment possibilities x Proven vehicle solution x Unique solution = Tender evaluation criteria
It is very complex task how to find optimum – how to set up evaluation criteria. Need same or similar accent on vehicle price and LCC.
Transport costs minimization (LCC) – producer influence

<table>
<thead>
<tr>
<th>LCC main parts</th>
<th>Tram producer influence: 0 – 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition costs of the vehicle</td>
<td>sum</td>
</tr>
<tr>
<td>Vehicle purchase costs</td>
<td>100%</td>
</tr>
<tr>
<td>Other financial costs</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Vehicle operating costs</strong></td>
<td>sum</td>
</tr>
<tr>
<td>Maintenance</td>
<td>sum</td>
</tr>
<tr>
<td>Preventive maintenance</td>
<td>90%</td>
</tr>
<tr>
<td>Corrective maintenance</td>
<td>90%</td>
</tr>
<tr>
<td>Repairs after collisions</td>
<td>30%</td>
</tr>
<tr>
<td>Cleaning</td>
<td>20%</td>
</tr>
<tr>
<td>Energy consumptions</td>
<td>20%</td>
</tr>
<tr>
<td>Other operating materials – sand, grease</td>
<td>5%</td>
</tr>
<tr>
<td>Salary costs</td>
<td>0%</td>
</tr>
<tr>
<td>Infrastructure costs</td>
<td>30%</td>
</tr>
<tr>
<td>Vehicle parking costs</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Vehicle liquidation costs</strong></td>
<td>1%</td>
</tr>
</tbody>
</table>

Necessity of LCC simulations for all different customers – deficit of relevant and correct information
Vehicle producer has influence approximately on 70 – 75% of LC costs. Vehicle operator has influence approximately on 25 – 30% of LC costs.

Producer can offer optimal solution but operator have to require optimal solution.
Škoda Transportation – Trams products

ForCity - modular, universal and reliable design solutions, ...

Product platform helps to reduce vehicle acquisition prices and increase reliability.

<table>
<thead>
<tr>
<th>NON-PIVOTING BOGIES</th>
<th>ID</th>
<th>Length</th>
<th>Basic configuration</th>
<th>Vehicle capacity (sitting/total *)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.3 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Uni</td>
</tr>
<tr>
<td>X32</td>
<td>20.87 m</td>
<td><img src="X32.png" alt="Image" /></td>
<td></td>
<td>38/112</td>
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<tr>
<td>X53</td>
<td>31.00 m</td>
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<tr>
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<tr>
<td>X95</td>
<td>52.36 m</td>
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<td>101/309</td>
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</tbody>
</table>
### Škoda Transportation – Trams products

#### ST - modular design

<table>
<thead>
<tr>
<th>ID</th>
<th>Length</th>
<th>PIVOTING BOGIES</th>
<th>Basic configuration</th>
<th>Vehicle capacity (sitting/total *)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(ST1)</td>
<td></td>
<td>2.3 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.4 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.5 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.65 m</td>
</tr>
<tr>
<td>X12</td>
<td>16.82 m</td>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
<tr>
<td>X23</td>
<td>20.98 m</td>
<td><img src="image7" alt="Diagram" /></td>
<td><img src="image8" alt="Diagram" /></td>
<td><img src="image9" alt="Diagram" /></td>
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<tr>
<td>X34</td>
<td>37.14 m</td>
<td><img src="image13" alt="Diagram" /></td>
<td><img src="image14" alt="Diagram" /></td>
<td><img src="image15" alt="Diagram" /></td>
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<tr>
<td>X45</td>
<td>43.90 m</td>
<td><img src="image19" alt="Diagram" /></td>
<td><img src="image20" alt="Diagram" /></td>
<td><img src="image21" alt="Diagram" /></td>
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<tr>
<td>X56</td>
<td>53.50 m</td>
<td><img src="image25" alt="Diagram" /></td>
<td><img src="image26" alt="Diagram" /></td>
<td><img src="image27" alt="Diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID</th>
<th>Length</th>
<th>PIVOTING BOGIES</th>
<th>Basic configuration</th>
<th>Vehicle capacity (sitting/total *)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(ST2)</td>
<td></td>
<td>2.3 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.4 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.5 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.65 m</td>
</tr>
<tr>
<td>X12</td>
<td>15.32 m</td>
<td><img src="image31" alt="Diagram" /></td>
<td><img src="image32" alt="Diagram" /></td>
<td><img src="image33" alt="Diagram" /></td>
</tr>
<tr>
<td>X23</td>
<td>21.35 m</td>
<td><img src="image37" alt="Diagram" /></td>
<td><img src="image38" alt="Diagram" /></td>
<td><img src="image39" alt="Diagram" /></td>
</tr>
<tr>
<td>X34</td>
<td>29.21 m</td>
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<td><img src="image44" alt="Diagram" /></td>
<td><img src="image45" alt="Diagram" /></td>
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<tr>
<td>X45</td>
<td>35.97 m</td>
<td><img src="image49" alt="Diagram" /></td>
<td><img src="image50" alt="Diagram" /></td>
<td><img src="image51" alt="Diagram" /></td>
</tr>
<tr>
<td>X56</td>
<td>47.15 m</td>
<td><img src="image55" alt="Diagram" /></td>
<td><img src="image56" alt="Diagram" /></td>
<td><img src="image57" alt="Diagram" /></td>
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</tbody>
</table>
Škoda Transportation – Trams products

ST - modular design

PIVOTING AND NON-PIVOTING BOGIES (COMBINATION)

<table>
<thead>
<tr>
<th>ID</th>
<th>Length</th>
<th>Basic configuration</th>
<th>Vehicle capacity (sitting/total *)</th>
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<tbody>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Uni</td>
</tr>
<tr>
<td>X33</td>
<td>30.08 m</td>
<td></td>
<td>57/169</td>
</tr>
<tr>
<td>X54</td>
<td>41.36 m</td>
<td></td>
<td>51/121</td>
</tr>
<tr>
<td>X33</td>
<td>23.66 m</td>
<td></td>
<td>51/121</td>
</tr>
<tr>
<td>X54</td>
<td>34.03 m</td>
<td></td>
<td>51/121</td>
</tr>
</tbody>
</table>

* ~ 4 passengers/m²
| ForCity platform – product portfolio |

<table>
<thead>
<tr>
<th>ForCity Alfa</th>
<th>ForCity Classic</th>
<th>ForCity Smart</th>
<th>ForCity Plus</th>
</tr>
</thead>
</table>

- **Axlebridge**
  - Independent wheels

- **Axle**
  - Standard wheelset

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Jiří Vokoun – 11.11.2014, LRD
Product portfolio – ForCity bogie generation (Low Floor)

First generation
- Axlebridge
- Pivoting bogie
- Gauge 1000, 1435, 1524

Second generation
- Axle
- Rigid & pivoting bogie
- Gauge 1000, 1435

Third generation
- Axle
- Rigid & pivoting bogie
- Gauge 1000, 1435
- 2nd
  - Suspended propulsion set
  - Also air cooled motor

Modernization of the second generation
# Škoda Transportation – Trams products

## Projects – ForCity family realizations

<table>
<thead>
<tr>
<th>ForCity Alfa – 15T, 15T Riga</th>
<th>ForCity Classic – 26T, 28T, …</th>
<th>ForCity Plus – 29T, 30T</th>
<th>ForCity Smart – …T</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="ForCity Alfa" /></td>
<td><img src="image" alt="ForCity Classic" /></td>
<td><img src="image" alt="ForCity Plus" /></td>
<td><img src="image" alt="ForCity Smart" /></td>
</tr>
</tbody>
</table>

- **ForCity Alfa – 15T, 15T Riga**
  - 15T – Prague spec
  - 3 section tram
  - One directional tram (optional two directional)
  - Solo operation
  - 4 pivot bogies (4 traction)
  - Axlebridge bogies
  - Independent wheels
  - 12-16 synchronous motors
  - No gear boxes
  - 12 - 16 IGBT converters

- **ForCity Classic – 26T, 28T, …**
  - 26T – Miskolc spec
  - 28T – Konya spec
  - 5 sectional tram
  - Two directional tram
  - 28T operation in combination
  - 3 rigid bogies (2 traction)
  - Axle bogie
  - 4 asynchronous motors
  - 4 gear boxes
  - 2 IGBT converters
  - 28T tunnel operation
  - EN 15227

- **ForCity Plus – 29T, 30T**
  - 29T & 30T – Bratislava spec
  - 5 sectional tram
  - 29T one directional tram
  - 30T two directional tram
  - Solo operation
  - 2 pivot and 2 rigid bogies (3 traction)
  - Axle bogie
  - 6 asynchronous motors
  - 6 gear boxes
  - 3 IGBT converters
  - EN 15227

- **ForCity Smart – …T**
  - X34 – No spec
  - 3 sectional tram
  - One or two directional tram
  - Operation in combination
  - 4 pivot bogies (2-3 traction)
  - Axle bogie
  - 4-6 asynchronous motors
  - 4-6 gear boxes
  - Tunnel operation
  - EN 15227

### Generation Timeline

- **First generation**
  - 2008

- **Second generation**
  - 2011

- **Third generation**
  - 2013
  - 2015

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Jiří Vokoun – 11.11.2014, LRD
ForCity Alfa – Prague

Main design reasons

**Typical customer conditions:**
- Difficult operating track conditions
  - Small curve radii
  - High frequency of curves on tracks
  - Long and steep slopes
- Historically limited tracks profile – vehicle envelop
- High stops and stations frequency
- High comfort for passengers
- High comfort for drivers

**Vehicle solutions:**
- Low pair of wheels loading – lower loading of outer bogies
- Pivoting bogies
- 100% traction and EDB brake adhesion
- Vehicle dimensions and bogies position
- Maximal vehicle power $16 \times 46 = 736$ kW, maximal summative torque $16 \times 2270 = 36320$ Nm
- Inner bogies with two pivots and outer bogies with eccentric pivots – sufficient aisle width and 100% LF
- Driver’s cab with separate door and with high comfort

Skoda Transportation is able to developed fully new solutions on the market.
ForCity Alfa – Prague

Main vehicle characteristics

- Traction Bogie
- Comfort area
- Rapid exchange area
- Comfortable cab
## Basic parameters

- **Car length:** 31 400 mm
- **Car width:** 2 460 mm
- **Car height:** 3 600 mm
- **Gauge:** 1 435 mm
- **Floor height:** 320 – 350 – 450 mm
- **Low-floor part:** 100 %
- **Sitting + standing (4/6/8 Pers./m²):** 61 + 120/ 179/239
- **Maximal axle loading:** 7/9,5 t (outer/inner bogie)
- **Drive motor (power/torque (max.)):** 16 x 46 kW / 2 270 Nm
- **Speed max.:** 60 km/h / 70 km/h
- **Traction motors (type/cooling):** Synchronous / water
- **HVAC: Driver/Passengers:** Yes / Optional

![Diagram of the ForCity Alfa - Prague tram](image)
Bogie

**Characteristics**

- Advanced design based on long-time experience of Škoda Transportation a.s.
- Minimization height of components assembling for low tram floor.
- Optimized design of bogie frame.
- Bogie frame is a cast end weld design. Axle bridges are a cast design.
- Independent wheels for good and sophisticated wheels rotation control.
- Large wheel diameter.
- Four synchronous water cooled motors per one motor bogie. Connection between motor and wheel by flexible clutch.
- Propulsion without gearboxes.
- Optimal power parameters and high adhesion ratio.
- Minimization of unsuspended weights – no gearbox, flexible clutch between motor and wheel.
- Maximal axle loading 7 t/9,5 t (outer/inner bogie)
- Easy accessible motors
- Free swiveling of the bogie.
- Excellent ride quality.
- Used features for internal and external noise minimization

**Technical data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauge</td>
<td>1 435 mm</td>
</tr>
<tr>
<td>Wheel base</td>
<td>1 900 mm</td>
</tr>
<tr>
<td>Wheel diameter (new/worn)</td>
<td>666/586 mm</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>70 km/h</td>
</tr>
<tr>
<td>Maximum axle load (outer/inner bogie)</td>
<td>7/9,5 t</td>
</tr>
<tr>
<td>Maximal power</td>
<td>4 x 46 kW</td>
</tr>
</tbody>
</table>

Thanks to suitable arrangement of bogies the ForCity vehicle can combine the 100% low-floor and freely pivoting bogies also for narrow gauge.
Main design reasons

**Typical customer conditions:**
- High capacity of the vehicle
- Sufficient vehicle parameters and performance
- Low price of the vehicle
- High reliability of the vehicle
- Low life cycle cost

**Vehicle solutions:**
- Standard conception of the vehicle – 75% of sales in last 5 years
- Standard and proven technical solutions
- Accent to low weight of the vehicle
- 4 traction motors with sufficient performance parameters
- Number of different parts minimization
- Used proven components from previous projects
- Service and maintenance rules respectation

Skoda Transportation is ready to offer standard solution with proven conception and design.
ForCity Classic – Miskolc

Main vehicle characteristics

- Traction Bogie
- Idle Bogie
- Comfort area
- Rapid exchange area

Jiří Vokoun – 11.11.2014, LRD
ForCity Classic – Miskolc

Basic parameters

- Car length: 32 100 mm
- Car width: 2 650 mm
- Car height: 3 560 mm
- Gauge: 1 435 mm
- Floor height: 330 – 360 – 495 mm
- Low-floor part: 100 %
- Sitting + standing (4/7.28 pers./m²): 56 + 164/298 = 220/354
- Maximal axle loading: 11/12,5 t (outer/inner bogie)
- Drive motor (power/torque (max.)): 4 x 200 kW / 1 060 Nm
- Speed max. (operation/design): 60 km/h / 70 km/h
- Traction motors (type/cooling): Asynchronous / water
- HVAC: Driver/Passengers: Yes / Yes
ForCity Classic – Miskolc – Basic features

Bogie

- Primary suspension minimize unsuspended weights
- Optimized secondary suspension
- Easy accessible traction motor and disc brake
- Easy accessible Gearbox
- Casting bogie frame
- Easy accessible Mechanical disc brake
ForCity Classic – Miskolc – Basic features

Bogie

<table>
<thead>
<tr>
<th>Characteristics</th>
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<tbody>
<tr>
<td>- Design based on long-time experience of Škoda Transportation a.s.</td>
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<td>- Minimization height of components assembling for low tram floor.</td>
</tr>
<tr>
<td>- Optimized design of bogie frame.</td>
</tr>
<tr>
<td>- Bogie frame is a cast design.</td>
</tr>
<tr>
<td>- Rigid axles for good running property of the vehicle.</td>
</tr>
<tr>
<td>- Two asynchronous water cooled motors per one motor bogie.</td>
</tr>
<tr>
<td>- Optimal power parameters.</td>
</tr>
<tr>
<td>- Minimization of unsuspended weights.</td>
</tr>
<tr>
<td>- Maximal axle loading from 11 t to 12,5 t.</td>
</tr>
<tr>
<td>- Easy accessible motors, gearboxes and mechanical disk brakes for service.</td>
</tr>
<tr>
<td>- Limited swiveling of the bogie.</td>
</tr>
<tr>
<td>- Excellent ride quality.</td>
</tr>
<tr>
<td>- Bogies protected against fouling.</td>
</tr>
<tr>
<td>- Optimized bogie to car body connection.</td>
</tr>
<tr>
<td>- Used features for internal and external noise minimization</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Technical data</th>
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<td>Wheel base</td>
<td>1 800 mm</td>
</tr>
<tr>
<td>Wheel diameter (new/worn)</td>
<td>620/540</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>70 km/h</td>
</tr>
<tr>
<td>Maximum axle load (traction/trailer)</td>
<td>11/12,5 t</td>
</tr>
<tr>
<td>Continuous power</td>
<td>2x100 kW</td>
</tr>
</tbody>
</table>
Main design reasons

**Typical customer conditions:**
- Limited axle loading – maximally 11 t/axle (preferred 10 t/axle)
- Requirement for pivoting bogie - minimally first bogie in driving direction
- Narrow gauge 1000 mm
- Small radius of horizontal curves – 25/19 m
- Passengers comfort – slopes and aisle width
- Sufficient number of doors
- Requirement for vehicle capacity – length of the vehicle
- Limited tracks profile – vehicle envelop
- Low floor ratio maximization

**Vehicle solutions:**
- Five sectional tram with four bogies
- Outer bogie below the cab (end of the tram)
- Vehicle conception with combination of pivot and rigid bogies

Skoda Transportation is able to find best solution for each customer.
ForCity Plus – Bratislava

Main vehicle characteristics

- Traction Bogie
- Idle Bogie
- Comfort area
- Rapid exchange area
- Comfortable cab
Basic parameters

- Car length: 32 495 mm
- Car width: 2 480 mm
- Car height: 3 560 mm
- Gauge: 1 000 mm
- Floor height: 350 – 380 – 515 mm
- Low-floor part: 87%
- Sitting + standing (4/8 pers./m²): 69 + 138/276 = 207/345
- Maximal axle loading: 10/11 t (outer/inner bogie)
- Drive motor (power/torque (max.)): 6 x 200 kW / 1 060 Nm
- Speed max. (operation/design): 65 km/h / 75 km/h
- Traction motors (type/cooling): Asynchronous / water
- HVAC: Driver/Passengers: Yes / Yes
Skoda Transportation is ready for very specific customer requirements.
Thank you for your attention!