PLATON –

Planning Process and Tool for Step-by-Step Conversion of the Conventional or Mixed Bus Fleet to a 100% Electric Bus Fleet

Deliverable 5.2: Report Generation
Part of milestone M4
Main Work package WP 5.6 Report Generation

Due Date: December 31, 2019

Report term: October 1, 2019 – December 31, 2019

Funding code: 03EMEN17

Project term: January 1, 2018 – June 30, 2020

Editor: Olaf Czogalla, ifak

Grant beneficiary of WP leader:
Institut für Automation und Kommunikation e.V.

Funding organisation of WP leader:
Bundesministerium für Verkehr und digitale Infrastruktur
Invalidenstraße 44
10115 Berlin

Contents

1 Introduction

The deliverable presents the results of the project work carried out by consortium partners in the WP 5.6: Report Generation.

The results of WP 5.6 are focused on the following aspects.

The planning process is rather complex and includes a lot of calls of the basic methods. It is important to make all the basic method calls, used parameters, obtained results and conclusions to the following basic method calls transparent and comprehensible to the user. Therefore, this task deals with the fully automatic creation of a detailed report including all this information as well as graphical representations of the results by an electronic document.

The present deliverable describes the task of report generation including example in connection with the information and data architecture of the developed PLATON Toolkit System and its components.

The report generation element of the PLATON Toolkit System is considered as an important output component for the decision support to be provided for the strategic planning level of a transit agency in function of its management board. Therefore, the required elements to be included in the generated report are determined by the kinds of decision problems to be supported by the PLATON Toolkit System.

The elements of the Report Generator component are described in the following contents of the document.

2 Requirements of the report generator tool component

The process of bus fleet electrification comprises all targeted efforts to introduce or increase the number of battery electric buses in fleets of local public transport agencies. Several domains are involved in these processes such as the legislative and governmental domain, the economic domain, the public transport domain and finally the electric power domain. Numerous dependencies exist between entities of the named domains which are described in detail by the authors but will be not further elaborated here.

However, for understanding of this highly dependent process it is essential to acknowledge that, derived from the interdependent relationships, there were identified multiple levels of the planning process itself. Therefore, exist a multi-layer structure of the planning process in the same sense, including bodies of stakeholders on these levels. At least three main level were distinguished, such as: i) the legislative-governmental level, ii) the strategic corporate planning level, and iii) the transport operations planning level.

Any set of tools, here named the Toolkit, designed to support the decision-making on these process levels i)-iii) is likely to function relatively autonomously with regard to each planning levels, but must be interoperable concerning data exchange with basic input data of the transport region of interest. An interface definition and documentation must contain not only the mathematical semantic description of the required input data contents but also the data model and data architecture in order to achieve the required interoperability.

For this reason, a dedicated Application and Data Architecture was derived and developed to ensure the interoperability and conformance to the dependency network as well as the distinguished planning levels that were identified. Interoperability is required to ensure a seamless data exchange between components of the PLATON Toolkit. There are numerous categories of data to be distinguished with respect to input data and output data. Input data is to be referred as the input to components of the toolkit. These can be output data of other tool components or data from open or proprietary sources. In Figure 1 is shown the information and data architecture between components of the PLATON Toolkit System.

The directed arcs between the green marked tool components represent flows of data objects from their source to their destination including the category and formats. Note that the planning levels addressed, are emphasized as strategic corporate planning level and transport operation planning level. Decision support will be provided in form of generated reports that comprise the most important output for strategic decisions such as TCO projection of the bus fleet, electrification priority of routes, procurement recommendation based on the configuration of vehicle, batteries and charging infrastructure.

More specific planning support is provided to the transport operations level such as scheduling for electric buses, opportunity charging locations or potential transit network adaptations with regard to the existing power grid under consideration of the transit demand.

The architecture reveals the data flow, interfaces and sources of data for the toolkit system which is developed to the extent of the shown information and data architecture.

For further reasoning it is assumed that for the purpose of decision support the legislative/governmental level and the strategic corporate planning level will be considered as combined. This is because of the shareholder structure in most public transport agencies of Europe and beyond. As a rule, it can be assumed that the public transport operator of a territorial community is owned with the majority of shares by the urban or regional administrative body that itself is authorized by the political legislative body.

Therefore, if the political will of bus fleet electrification is adopted by the legislation, the task of execution is in the hands of the government who itself will move forward resolutions in the corporate shareholder's assembly to be executed by the corporate management of the public transport agency.

Following this reasoning it is justified to provide economical, technical and operational decision support only to the strategic corporate planning level in the form of the CEO and the management board.

For the practical realization of the economical, technical and operational decision support a concise reporting document is generated to contain the basic results of total cost of ownership projection for the mid-term financial planning horizon, further a proposal for electrification priority of bus routes based on calculated kinetic intensity, a procurement recommendation based on the bus vehicle market research and battery configuration with opportunity or slow depot charging option. The concise reporting document is expected to provide and easy-to follow decision support by collection of output data from distinguished models of the information and data architecture, as shown in Figure 1.

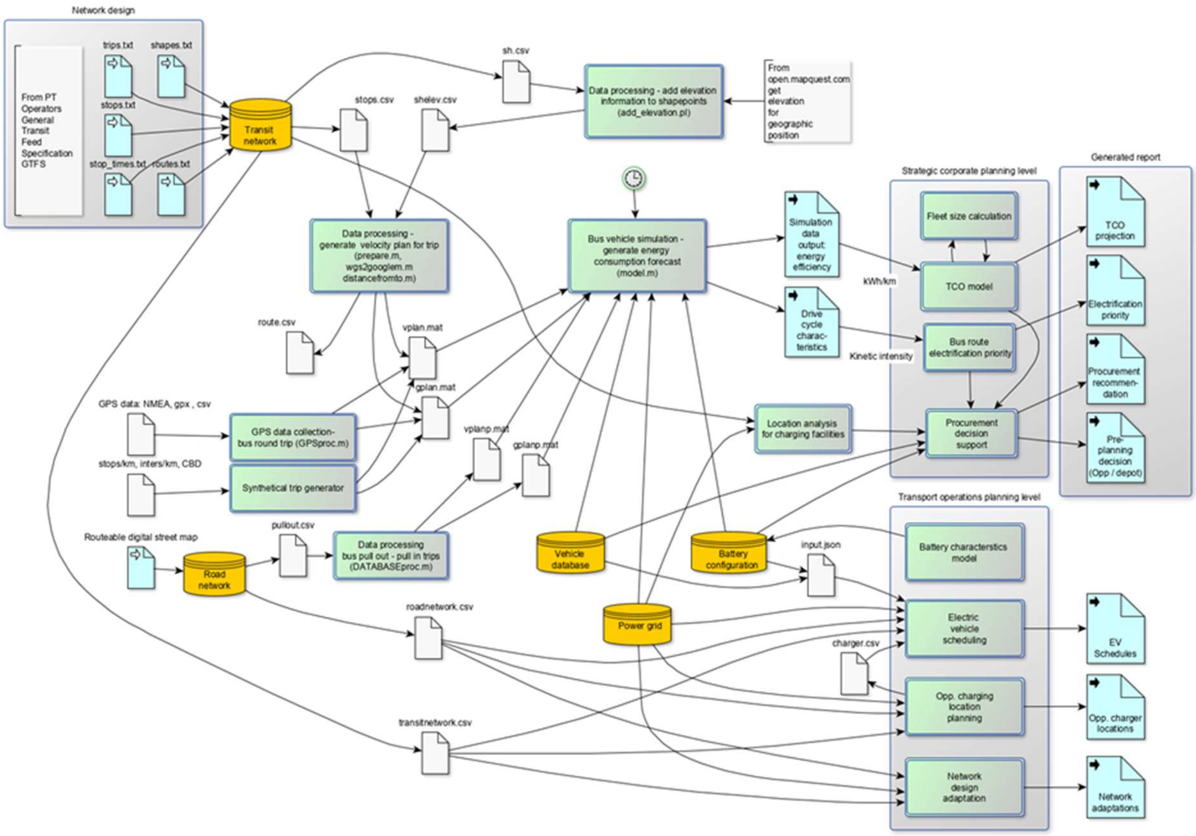

Figure 1 Information and data architecture of PLATON Toolkit System and its components

3 Integration interface between PLATON Toolkit components

From the Information and data architecture can be identified the informational flow of parameters, basic data and the output and input data throughout the planning process up to the step of report generation.

In Deliverable 3.2 Input data formats [4] chapter 2 on categories and formats the interfaces between the architectural elements are described in more detail. Basically three categories of data are defined: scalar quantities, vectorial quantities, sequences, matrices and other tabular data.

The utilized data categories can be classified by their properties such as type and cardinality. For example, the scalar parameters for the optimization tool component such as boundaries, physical quantities or financial costs are represented by variables with mnemonic names that are collected in and transferred by JSON files. The JSON format was selected for its efficiency with respect to data transfer and parsing capability. Since data structures supported by JSON is also supported by most of the modern programming languages, it makes JSON a very useful data-interchange format.

Data exchange between components of the PLATON Toolkit is also achieved by internal interfaces using internal files. These files are generated and used by elements of one tool component and are also intended to be used for data exchange between tool components.

4 Implementation of the Report Generator Tool

In the current stage of the project the Report Generator Tool Component of the PLATON Toolkit is implemented in the form of a program script for the Octave environment. In the continuation of the project and further integration stage of the PLATON Toolkit the software module is implemented in a higher language as an executable application.

5 Elements of generated report sheets

The basic elements of a report enabled to support economical, technical and operational subjects of the strategic corporate planning level are total cost of ownership projection, electrification priority, procurement recommendation and pre-planning relevant decision support on depot and/or opportunity charging.

The decision support is based on output data that is presented in concise and clear format on the generated report sheet.

For each of the elements models are used to generate the referring output data. In the following the input and output data of the generated decision support elements are given.

5.1 Total cost of ownership projection

Input data of the cost of ownership projection follows the description of input data formats in Deliverable 3.2 [4] are the following data sets:

- Vehicle / charger data:

  Data on bus capital cost for a 12m and 18m bus, charger capital cost, charger installation cost, midlife cost that must be given in the json-file `veh-ch-inp-data.json` as shown in Table 1.

  Table 1 Example of input file `veh-ch-inp-data.json`


```
{
  "buscapcost12":625000,
  "buscapcost18":900000,
  "chargercost":45000,
  "chargerinst":49100,
  "midlifecost":67000
}
```


  The json-file `veh-ch-inp-data.json` must reside in the same directory as the report generator software.

- Simulation determined or known efficiencies

  Data on efficiencies of the electric bus in kWh/km that are either determined by bus vehicle simulation or provided by manufacturer a 12m and 18m bus must be given in the json-file
  `veh-eff.json` as shown in Table 2.

  Table 2 Example of input file `veh-eff.json`


```
{
  "efficiency12":1.5,
  "efficiency18":1.7
}
```


  The json-file `veh-eff.json` must reside in the same directory as the report generator software.

- Energy and maintenance cost

  Data on energy cost in EUR/kWh and maintenance cost in EUR/km are provided by the transport operator and relates to industry energy supply contracts, as well as to internal accounting and must be given in the json-file `energy-cost.json` as shown in Table 3.

  Table 3 Example of input file `energy-cost.json`

```
{
  "avgfuelcost":0.15,
  "avgmaincost":0.67
}
```

  The json-file `energy-cost.json` must reside in the same directory as the report generator software.

- Fleet data

  Data on the routes and fleet of the transport operator are given in vectorial form. The route vector contains the identifiers for each route as a unique integer value. The peak headway vector contains the minutes between departures for the peak hour with the highest planned frequencies. The vector of departures per peak hour is given for additional information purposes. The return trip length vector for each route are given as known distances from the transport operator or can be determined by the map based component of the PLATON Toolkit (see Figure 1). The average speed in traffic including dwell times a stops is given for each route in km/h. The vector of articulated is given for routes that are services by 18m articulated vehicles. The data must be given in the json-file `fleet-data.json` as shown in Table 4.

  Table 4 Example of input file `fleet-data.json`

```
{
"params":
  {
  "route": [[51 52 53 54 55 56 57 58 59 61 69 71 72 73]],
  "peakheadway": [[20 20 20 20 20 60 20 20 60 60 20 60 20 10]],
  "deptperhour": [[3 3 3 3 3 1 3 3 1 1 3 1 3 6]],
  "rettriplen":  [[12.8  22.8  11.8  25.8  9.2  22.4  11.6  22.4  9.6  10.2
                  15.2 13.2 14.8 11.0]],
  "avgspeed":  [[32.0  20.1  22.1  24.2  19.2  26.9  23.2  24.9  18.0  19.1
                19.0 18.8 18.5 19.4]],
  "articulated": [[0 1 0 1 0 0 0 0 0 0 1 1 0 1]]
  }
}
```

The json-file `fleet-data.json` must reside in the same directory as the report generator software.

An example of the generated report (see the *Total cost of ownership analysis*) including input data and detailed results with yearly and annual TCO, energy consumption and yearly travelled distances, broken down to each of the given bus routes is shown in the Annex of this document.

5.2 Electrification priority

Input data of the electrification priority recommendation is the data set of kinetic intensity. The data set of kinetic intensity contains the calculated values of kinetic intensity for each route on the basis of either real-time collected acceleration data based on GPS measurements in the field. The collected data is post-processed by the GPSproc component of the PLATON Toolkit (see Figure 1).

The kinetic intensity data is given in vectorial form in the json-file `kinetic-intensity.json` as shown in Table 5.

Table 5 Example of input file `kinetic-intensity.json`


```
{
"params":
  {
  "kineticintensity": [[0 0 0 0 0 0 0 0 0 0 10.5 10.3 11.3 12.6]]
  }
}
```


The json-file `fleet-data.json` must reside in the same directory as the report generator software.

The electrification priority recommendation is based on the highest kinetic intensity to be determined for each of the examined routes. The higher the kinetic intensity the better a bus route is qualified for prioritized electrification if the alternative exists.

Further descriptions of the method of kinetic intensity analysis can be found in Deliverable 3.1 [3] in Chapter 5.5 Characterizing routes by means of kinetic intensity.

5.3 Procurement recommendation

The procurement recommendation includes the required type (12m/18m/articulated), required quantity for the given route including battery size dimension that are available on the market for a selected bus manufacturer, that is the make and the model.

Because the market of electric bus vehicles is very extensive as of the current time (see the list of Electric Bus Manufacturers as of December 2019) and as well as fast changing, a refined market research is indispensable at the time of the procurement recommendation is provided.

Therefore, a reasonable limitation of the bus manufacturers that would come into question would be advisable in in close coordination with the public transport agency as the client. An example of the list id given in the Annex: Limited list of Electric Bus Makes and Models as of December 2019. Because of the fast changing markets, a limited list is built on the basis of the most important parameters that are determined by the requirements of the public transport agency.

An example of a limited selection of manufacturers and makes are given in the Annex of this document in the Limited list of Electric Bus Makes and Models as of December 2019. The list contains make and models from China and Europe that have been introduced to the markets less than two years ago. Important parameters that are essential for the Bus vehicle simulation component of the PLATON Toolkit (see Figure 1) are included in the table. The table is in the current project status maintained with Excel.

Data from the table is fetched from the row of the bus make/model of interest and fed including the header line of the table into an available CSV to JSON conversion tool (see http://www.convertcsv.com/csv-to-json.htm). The converted output is saved into an JSON file (see Table 6) to be further processed by Bus vehicle simulation component of the PLATON Toolkit (see Figure 1).

Table 6 Example of input file `bus-params.json`

```
[
 {
   "Make": "e_citaro",
   "A_f": 7.844,
   "r_w": 0.47825,
   "length": 12,
   "m_empty(GVW)": 19500,
   "m_load": 6000,
   "passengers": 86,
   "maxRPM": "",
   "maxTorque": 970,
   "maxPower": 250000,
   "G": "",
   "Batt_Capacity": 243000,
   "Accessory_load": "",
   "V_oc": "",
   "R_int": "",
   "C_d": "",
   "Remark": ""
 }
]
```

The json-file `bus-params.json` must reside in the same directory as the report generator software.

5.4 Pre-planning charging decision

In order to support the decisions on charging configurations as described in the Deliverables 2.1 on Requirements [1], Deliverable 2.2 Planning Process [2] and Deliverable 4.3 on Efficient Charging Infrastructure [7] and Deliverable 4.4 – Efficient Planning Process [8] the pre-planning charging decision is targeted at the strategic alternative of using depot charging (DC) only or using a combination of depot charging and opportunity charging (OC) at terminal stops in the entire bus fleet electrification project.

In the context of this Deliverable 5.2 [10] it is stated that this decision is to be made in an early planning stage as it has remarkable influence on all following planning stages, the size of the bus fleet, the locations of charging stations, the size of battery packs, schedule adjustments, the power supply availabilities and many other aspects that influence the total cost of ownership. Therefore, it is called the Pre-Planning charging decision, that is in the sense of before procurement planning starts.

In Deliverable 4.1 [5] chapter 2.2 this aspect has been thoroughly described. In any case, this decision has to be made on the basis of profound calculations and vehicles-on-the-route-simulations using the components of the PLATON Toolkit. In result of these processing steps there will be a comparison of TCO in x EUR/km for the DC only case and between y EUR/km for the (DC-combined) OC case.

The values of the output data for the DC/OC-cases are included in the generated report to provide a substantial basis for decisions made by the corporate management.

6 References

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10. Czogalla, O.: *Platon - Planning Process and Tool for Step-by-Step Conversion*, Deliverable 5.2 – Report Generator, December 2019, available at http://service.ifak.eu/PLATON-Web/Platon-Deliverable-5.2-final.pdf

7 Annex

```
Total cost of ownership analysis
Transit agency: Magdeburger Verkehrsbetriebe GmbH & Co. KG

INPUT DATA

Capital cost of 12m bus      (EUR)   = 625000
Capital cost of 18m bus      (EUR)   = 900000
Capital cost charger equip   (EUR)   = 45000
Capital cost charger equip   (EUR)   = 45000
Install cost charger equip   (EUR)   = 49100
Midlife cost                 (EUR)   = 67000
Efficiency of 12m bus     (kWh/km)   = 1.5
Efficiency of 18m bus     (kWh/km)   = 1.7
Average fuel cost         (EUR/kWh)  = 0.15
Average maintenance cost  (EUR/km)   = 0.67

Bus routes    Peak headway (mins)    Departures (per h)   Return trip length (km)   Avg speed
(km/h)
   51.00   20.00    3.00   12.80   32.00
   52.00   20.00    3.00   22.80   20.10
   53.00   20.00    3.00   11.80   22.10
   54.00   20.00    3.00   25.80   24.20
   55.00   20.00    3.00    9.20   19.20
   56.00   60.00    1.00   22.40   26.90
   57.00   20.00    3.00   11.60   23.20
   58.00   20.00    3.00   22.40   24.90
   59.00   60.00    1.00    9.60   18.00
   61.00   60.00    1.00   10.20   19.10
   69.00   20.00    3.00   15.20   19.00
   71.00   60.00    1.00   13.20   18.80
   72.00   20.00    3.00   14.80   18.50
   73.00   10.00    6.00   11.00   19.40

RESULTS

Bus routes    Yearly TCO (EUR)    Energy consumption (kWh)   km travelled
        51.00    259053.27    252288.00    168192.00
        52.00    966229.11   1018612.80    599184.00
        53.00    238814.74    232578.00    155052.00
        54.00   1093364.52   1152640.80    678024.00
        55.00    186194.54    181332.00    120888.00
        56.00    226671.61    220752.00    147168.00
        57.00    234767.03    228636.00    152424.00
        58.00    680014.84    662256.00    441504.00
        59.00     97144.98     94608.00     63072.00
        61.00    103216.54    100521.00     67014.00
        69.00    483114.56    509306.40    299592.00
        71.00    139848.95    147430.80     86724.00
        72.00    449295.52    437562.00    291708.00
        73.00    466163.17    491436.00    289080.00

Annual  TCO of 12m bus      (EUR)   = 145598.4161
Monthly TCO of 12m bus      (EUR)   = 12133.2013
Annual  TCO of 18m bus      (EUR)   = 196795.0198
Monthly TCO of 18m bus      (EUR)   = 16399.585
Annual  EUR/km of 12m bus           = 1.5402
Annual  EUR/km of 18m bus           = 1.6126
```

List of Electric Bus Manufacturers as of December 2019

Manufacturer	Make/Model	Country
ABB & King Long Motor Group	TOSA	Switzerland
Alstom	Aptis	France
Alexander Dennis	Enviro500EV	UK
Astonbus	Astonbus	US
Astra Bus	Citelis	Romania
Avass	12 mt Full Electric City Bus	Australia
Belkommunmash	Vitovt Electro	Belarus
Bolloré	Bluebus SE	France
BredaMenarinibus	Zeus M-200 E model	Italy
BONLUCK	Citystar	China
BYD	K9, K12	China
CaetanoBus	e.City Gold	Portugal
City Smile	Ursus	Poland
Complete Coach Works	retrofitter	US
Ebus	retrofitter	US
Ebusco	Ebusco 2.2 City Bus	NL
Eurabus	Eurabus 3.0	Germany
Ekova	EKOVA Electron	Czech Republic
Electron	ELECTRON	Ukraine
Environmental Performance Vehicles	Tindo	NZ
Gépébus	Oréos	France
GreenPower Motor Company	EV350	Canada
Heuliez	GX 337 Elec bus	France
Iveco	EuroPolis	Italy
KamAZ	KamAZ-6282	Russia
Karsan	Jest electric	Turkey
Kayoola	Solar bus	Uganda
LiAZ	LiAZ-6274	Russia
Linkker	Linkker	Finland
Lujo EV	Lujo YX	China
MAN	MAN Lion's City 18E	Germany
Mercedes-Benz	eCitaro	Germany
New Flyer Industries	XCELSIOR Charge	Canada
Nova Bus	LFSe	Canada
Optare	Metrocity	UK
Ottokar	e-Kent C	Turkey
Proterra	Catalyst	US
PVI	Gepebus (Oréos)	France
Smith Electric Vehicles	Speedster	US
Solaris	Urbino 12,18 electric	Poland
Tecnobus	Gulliver	Italy
Temsa	Avenue Electron, MD 9 electri-	Turkey
URSUS	Ursus City Smile 10/12/18E	Poland
VanHool	Exqui.City 18 Electric	NL
VDL Bus & Coach	Citea Electric	NL
Volvo	7900 electric	Sweden
Wuzhoulong	FDG6113EVG City bus	China
YTONG	Ytong-E12	China
Zonda Bus	YCK6128HEC	China

Limited list of Electric Bus Makes and Models as of December 2019

	A_f	r_w	length	m_empty(GVW)	m_load	passengers	maxRPM	maxTorque	maxPower	G	Batt_Capacity	Accessory_load	V_oc	R_int	C_d	Remark
	m²	m	m	kg	kg	70kg/psg		Nm	W	final drive ratio	Wh	W	V	Ohm		
BYD K9	8.500	0.478	12	15440	2650	38	7500	700	180000	17.7	324000	5000	540	0.025	0.66	
E.Cobus 3000	9.300		12	20400	7800	111		1500	160000		85000	30000				for airports
e_citaro	7.844	0.47825	12	19500	6000	86		970	250000		243000					in 2018
Ebusco 2.1 City Bus	8.339	0.47825	12	12300	7200	103	3000	3000	220000		311000				0.79	
Heuliez GX 337 Elec	8.670		12	20000	7520	107		3300	190000		349000					
MAN Lion's City 12E	7.200		12						270000		480000					in 2020
MAN Lion's City 18E	7.200		18						540000		640000					in 2020
Sileo S12	8.415	0.47825	12	12850	6650	95		21000	240000		230000		500-700			
Solaris / Vossloh Kiepe	8.925		12	20480	7520	107			320000		37000					trolley bus
Solaris Urbino 12 Electric	8.657	0.47825	12	13790	5210	74		22000	250000		240000		600			
TEMSA Avenue Electron	8.160	0.47825	12	18600	6400	91		2700	250000		450000	35000				
Van Hool Exqui.City	8.415	0.47825	12	18500	8560	122	7000	2500	320000		215000					
VDL Citea SLF-120 Electric	8.798	0.47825	9-18	12600	6400	91		2500	160000		122000					
VOLVO 7900 Electric	8.364	0.47825	12/18	19000				400	160000		76000	28000	600		0.7	