PLATON –

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

Deliverable: 1 of WP 2 Requirements

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1 Introduction

The deliverable presents the work of the PLATON consortium partners aimed at describing the objectives and requirements to the PLATON planning process. The requirements analysis, because of the political, economic and ecological environment, may be different in countries of the consortium participants as well as in other member states of the European Union.

Therefore, we use various research methodologies to conduct requirement analysis as well as to define the objectives of the PLATON project. In the deliverable, foresight analysis is the basis for the assumptions for the fleet conversion model in the process approach. In the following part of the deliverable motivations and hindering arguments for fleet transiting are discussed. Based on those arguments, analysis of requirements of basic stages in transition to electric buses fleet is made. The key element of the deliverable is the dependency diagram showing dependencies between domains and their entities for electric bus deployment.

2 A foresight analysis

2.1 STEEP analysis

In order to find out the requirements for the transition of conventional fleet to 100% electric in local conditions, we employ a ***foresight analysis***, *defined as a process including: cooperation, discussions and consultations in the PLATON project environment: scientific, practitioners, users and authorities dealing with public transport in a broad sense, leading to the development of common methods of process planning, aimed at determining the long-term scientific, technological and practical conversion from a conventional bus fleet to 100% electric bus fleet.*

Expert panels are constructed within the project that will be a sufficiently large group of people competent to solve a specific problem, within a specified period resulting from the project schedule. As part of a technical partnership, external experts who are the representatives of various industries in transport, local government as well as Non-Governmental Organisations (NGOs) are participating in the panels as well.

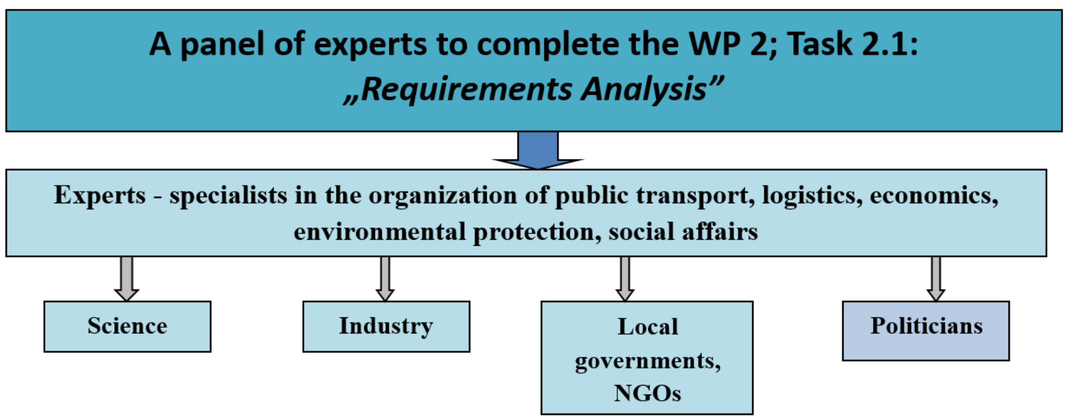

Figure 1. The structure of the panels of experts

In order to identify the problem, on the basis of which, a critical analysis for the replacement of conventional buses to electric ones will be made, one can use PEST (P-Political, E-Economic, S-Socio-cultural, T-Technological) methodology, that is the macroeconomic method of testing the external environment. A special variant of this method is STEEP (S-Socio-cultural, T-Technological, E-Economical, E-Ecological, P-Political). As the STEEP analysis additionally includes ecological issues, it seems to be more suitable for application in public transport.

The STEEP analysis should not be considered as a strict research procedure – it rather defines the most important cognitive issues determined by panel of experts that require in-depth assessment and critical analysis. The purpose of STEEP analysis is to prepare and agree a list of external (structural) factors conditioning the current state as well as the future development of electric-powered public transport. External factors describe these issues that determine the terms for the development of a given transport system, in the aspect of choosing proper methods for the conversion of a conventional bus fleet to 100% electric. It should be noted that some factors may be specific only for a territory analysed (province, country, European Union).

Based on the results of literature studies and expert workshops, a list of structural factors for particular groups of STEEP will be determined. The final list of factors will be reached by a targeted discussion, or by brainstorming. For the purpose of the system-dynamic analysis it will be necessary to verify the list of factors related to the induction of electric buses in public transport (social, technical, economic, ecological and political), developed by the STEEP panel (Fig. 2).

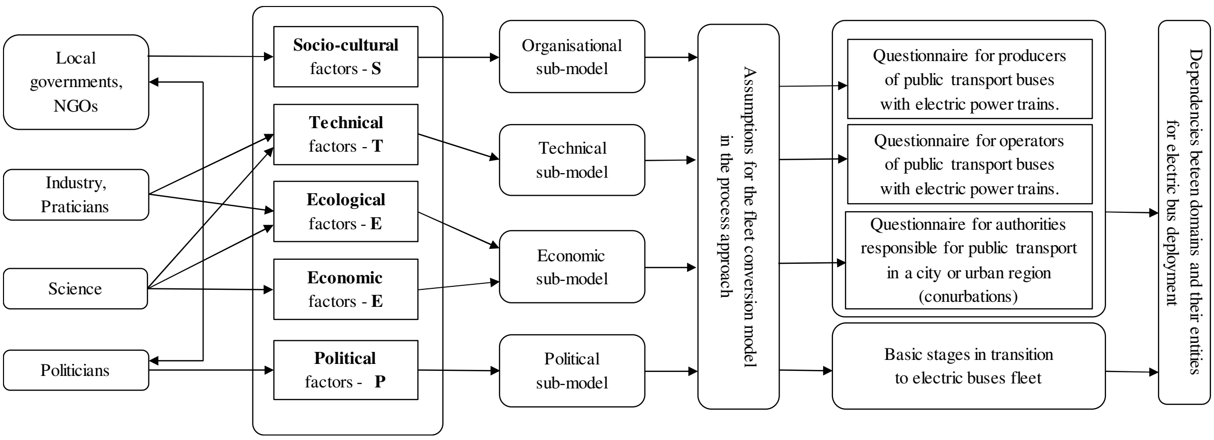

Figure 2. The structure of the conventional bus fleet conversion to 100% electric problem

On the basis of STEEP analysis, a list of the most important external factors is prepared for various stakeholders of the potential development of the electric bus fleet, with the investment possibilities assumed, ordered according to the criteria of validity and feasibility (Fig. 3). The criterion of the importance (attractiveness) of the project should be assigned to: economic, social, environmental and legal importance as well as the possibility of creating new directions of research and innovative implementations in public transport. The feasibility criterion are the application and implementation potential of the external factor.

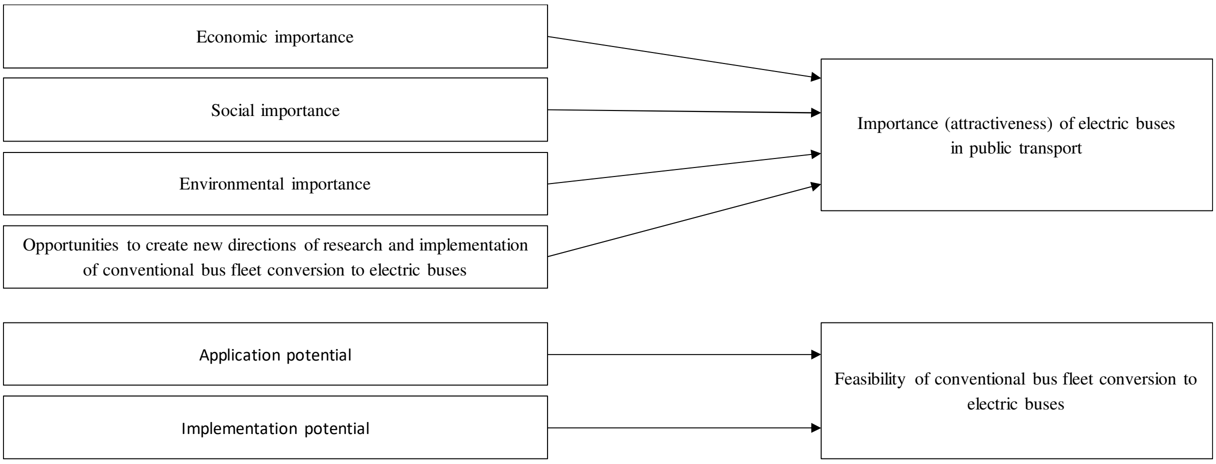

Figure 3. Criteria for the validity and feasibility of the conventional bus fleet conversion to electric buses

In Fig 3., importance is understood as the attractiveness of a given external factor, leading to a complete replacement of the fleet of conventional buses by electric ones and are to be assessed from the point of view of its technical, economic, social, environmental and political characteristics. The results obtained by STEEP method can be used to determine the assumptions for the fleet conversion model in the process approach.

2.2 Requirement analysis and a process approach

The assumptions for the fleet conversion model in the process approach include the following issues:

- Staging of the fleet conversion process
- Variation of activities adapted to established stages
- Variation of the fleet structure
- Strategies for the conversion covering the above issues regarding the aspirations (requirements and expectations of subsequent groups of stakeholders)

It is assumed that the fleet conversion process may take place in various stages, with the implementation of various activities and taking into account the different fleet structure (initial structure, target structure and transition structure).

The process approach to the bus fleet conversion problem, assumes the mapping of bus operation processes in the following conditions:

- In the operational aspect of the bus fleet, conducting transport tasks in a specific area
- In the functional aspect of the bus operator, acting on commission of public transport organiser (e.g. municipality) in a specific area
- In the socio-economic aspect of local government authorities

- In the aspect of transport policy and sustainable development, at the following levels: city/commune, agglomeration/metropolis, region/subregion, province/country, Europe/world

System components to be included in conversion processes are:

- Stakeholder groups: passengers, NGOs representing passengers, national and local government authorities, (regional) transport organisers, carriers, bus producers, battery producers, producers of charging systems, energy suppliers, standardisation bodies, research and development centres, owners of the respective system components (bus, infrastructure, power lines)
- Stakeholder aspirations: requirements and expectations of respective stakeholder groups
- Functional characteristics of propulsion technologies
- Transport systems of the area: individual and public
- Organisational characteristic of bus public transport:
    - Organiser
    - Carriers (operators)
    - Characteristics of grid operators for specific types of power supply
    - Bus route network operated by respective organisers and operators
- Functional characteristics of bus transport, including:
    - The structure of the fleet: the number of buses divided into:
        - Propulsion technology (Diesel, CNG, LNG, hybrid-electric, battery electric, catenary-electric)
        - Type of propulsion power systems (technical infrastructure, suitable for Diesel, CNG, LNG, hybrid and battery electric buses, catenary-electric)
        - Functional and technical characteristics of the fleet: number of passengers, unitary fuel or electricity consumption and other parameters relevant to the fleet conversion process
    - Characteristics of the routes served by the buses:
        - Vertical profile of routes (vertical inclination values, grades)
        - Location of bus stops, schedule, bus movement
        - Road traffic condition, including: the number of stops at intersections (use of brakes for energy recuperation for recharging the battery) and deceleration associated with the congestion (lack of efficient bus traffic with simultaneous use of battery power for on-board installations – lighting, air conditioning, heating, ventilation, electrical steering support, passenger information systems etc.)

- Characteristics of the area served by particular bus routes in terms of factors favourable and unfavourable for particular type of propulsion
- Other system elements identified in the next stages of designing the fleet conversion process

Above mentioned conditions should be mapped in the bus fleet conversion process in the form of variables describing system states in this process. The analysis of these conditions will enable the identification of the factors and their impact on the fleet conversion process thanks to which it will be possible to prepare an appropriate set of activities that will be subjected to stage and scheduling in the multi-criteria optimisation process. Division into stages and scheduling are related to the adopted fleet conversion strategy, which nature should meet specific aspirations (requirements and expectations) of specific stakeholder groups.

The tool of fleet conversion model to be implemented should be a multimodal application, operating in the expert system mode. The expert system should adjust the range of the entered data as well as the scope and manner of presenting the results to the group of stakeholders and their aspirations. The presentation of the results should include, inter alia:

- A descriptive part of the fleet conversion strategy
- A list of activities grouped into stages of the task-chronological order
- An assessment of individual activities and the entire bus fleet conversion strategy, based on SWOT/TOWS analyses in the context of STEEP analysis – a compliance of actions and strategies with the political, ecological, economic, socio-cultural and technological conditions, with the particular emphasises on sustainable development and urban mobility.

In order to shorten the application running time for stakeholders from a given area, it is advisable to implement the basic scope of the usage data (including the functional characteristics of public transport) into the appropriate database.

3 Motivations and hindering arguments for transiting

The project aims at developing tools supporting transiting to a 100% electric fleet. A typical categorisation of tools has to follow the phases of the decision making process[1]. Additionally transition to 100% electric needs a stimulus, so we may list the following steps:

- Motivation initiating the transition process

[1] Franz, A. (2017, 3 7). *The Five Phases of Decision-Making*. Retrieved from Qualitydigest: https://www.qualitydigest.com/inside/management-column/five-phases-decision-making-part-1-030717.html#

- Defining and analysing the transition problems
- Developing alternate solutions
- Choosing the best suited solution
- Supporting the conversion into effective action

One of the problems starting a transition is to operate a large fleet of diesel buses by having no experience with electric power trains or power substations for trams or trolley buses. It might be easier transiting, if there are power substations from an existing trolley bus network or an extensive tram network but the analysis is left over to the construction of alternative solutions.

The motivation for transiting might include:

- Reducing gaseous emission from diesel engines, but also partly from mechanical brakes
- Improving living quality in cities, reducing noise emissions from buses
- Replacing expenses for imported fuel by local investments in renewable power infrastructure – shifting money flow from oil exporting countries to reliable trade partners, and possibly regional battery producers.

On the other hands the hindering arguments are:

- Fear that financing of cost intensive electric systems is not feasible or would require either cost cutting or fares surging, leading to decreasing transport demand
- Necessity of dealing with two different propulsion technologies during the transition, binding resources
- Breaking up existing management and procurement processes, dealing with new contractors/manufacturers where reliability and service quality is unknown
- Absence of competencies for electric power trains and charging infrastructure risking a successful operation of public transport in the city
- Fear that qualified drivers – a scarce resource - are reluctant to follow over to electric power trains creating a human resources problem

The most important questions when planning a transition to 100 % electric propulsion are:

- Fear that qualified drivers – a scarce resource - are reluctant to follow over to electric power trains creating a human resources problem?
- Where does the enterprise stand in the cyclic renewal of diesel buses?
- How many systems are operated resp. what internal departments do exist (also for electric vehicles like tramway, trolley or solely for diesel busses)?

Additionally, space demand for opportunity charging and cultural heritage issues – protecting historic centres – are limiting factors when installing overhead charging facilities.

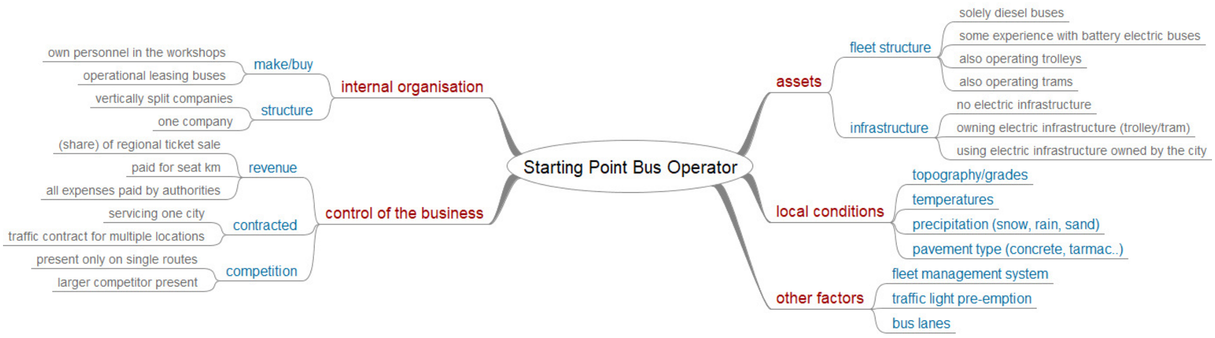

Figure 4. Starting point for bus operators

The public transport operators are facing various starting position in terms of technical but also organisational dimensions

4 Questionnaire among manufacturers, operators and local authorities as a tool to study fleet conversion needs

In order to determine the functionalities, requirements and recommendations for the development of a tool to support the conventional bus transition process, the use of the survey method was proposed. Three main groups of stakeholders have been distinguished: bus manufacturers, public transport operators and representatives of local authorities.

On the basis of expert knowledge, a separate questionnaire for each group was prepared. Individual questionnaires are dictated by the varied impact of a given group on the conversion. Answers to the questions contained in a given group in the questionnaire will allow to check the needs of stakeholders in relation to the developed PLATON tool. On the basis of the information obtained, basic methods will also be indicated to improve the conversion process of a bus fleet to a share of 100% electric propulsion. The consortium acknowledges that 100% may only be applied to suitable routes of a bus operator, excluding buses for special duties.

Currently, work on the final content of questionnaires is underway. The questionnaires are available at the following address: www.publictransport.info. The questionnaires were developed in XML format and their content on the server was included. Each survey begins with a short introduction that describes the purpose of the project and the partners involved in its implementation. Three types of questions were used in the survey: open, multiple and one-choice. In order to increase the usability and transparency of the questionnaire, the questions were sorted into thematic groups. Each topic of the survey was finished with an additional text field, allowing to entering one's comments.

Facilitating PLATON's questionnaires to the practitioners allows for direct recording of responses to the database, which enables analysis and preparation of a questionnaire survey report. All the entered online data will be anonymous, only information about the country of origin of the respondent will be recorded. Questioning operators will be made face to face if necessary.

4.1 Questionnaire for producers of public transport buses with electric power trains

The questionnaire addressed to bus producers of public transport buses with electric power trains contains 22 questions, divided into 7 subjects:

- Your offer
  - Propulsion systems offered
  - Energy storage systems offered
  - Type of electric bus offered
  - Operational time of the bus without recharging
  - Range of the bus
  - Topographical limits
- Transition Support
  - Simulation software/other tool for pre-planning electric bus operation
  - Collaboration with other entities to support public transport operators when transiting to electric bus fleets
  - Hurdles for public transport operators to acquire data for vehicle simulation
- Human Resources
  - Deficiencies with bus operators when servicing (maintaining) battery electric vehicle in-house
  - Deficiencies with bus operators setting up projects with electric buses
- Special Offer
  - Supporting ECODRIVING schemes
  - supporting on-line transmission of the state of charge SoH and other data like battery temperature for managing the fleet
- Infrastructure
  - Charging options
  - Thermal regulation for parked buses while charging
- Transition Strategy
  - Favourites in terms of conversion strategy to 100% electric buses
  - Risk in term of skipping opportunity charging technology (charging at some stops), switching directly to battery electric buses (charged in the depot) when transiting to 100% electric operation

  - Adapting existing established bus routes in practice, adapting them to re-charging needs
  - Kind of procurement support to offer bus operators
  - Co-operation with other entities, easing transition to electric buses
- Statistics - about your enterprise
  - Amount of buses being sold per year

4.2 Questionnaire for operators of public transport buses with electric power trains

The questionnaire addressed to bus operators of public transport buses with electric power trains contains 66 questions, divided into 8 subjects:

- Statistics and general questions
  - Country of origin
  - Entity that is ordering transport operations
  - Bus fleet size and the type of propulsion
  - Kind of a weekly schedule operated
  - Maximum time the bus is operated on weekdays
  - Maximum distance driven by the bus per day
- Available data
  - Positional or odometric data (position, speed over time) of the bus lines and its format
  - Identification of actual bus stops for passenger exchange from available data
  - Hurdles for acquiring data for calculating actual power demand of the vehicles
  - Degree of detail of the data on energy consumption
  - Format of timetable data to possible to be exported
- Human Resources
  - Maintaining (service) of battery electric vehicles in-house
  - Operating ECODRIVING schemes
- Routes and Traffic Control
  - A structure of bus network
  - Topography of the bus routes
  - Traffic control at intersections (bus priority)

  - Assigning electric buses to routes and transport tasks
  - Time buffers for battery charging
  - Relocating (moving) of waiting zones, where buses might be charged during pausing
  - Presence of a back-up system where buses including drivers are located in the city and may step in case of broken down buses
  - Real time telematics system for vehicle control and communication including Automatic Vehicle Location AVL
- Infrastructure
  - Setting up opportunity/depot charging stations for electric buses
  - Difficulties in developing the charging infrastructure for electric buses
  - Battery charging technology operated and factors influencing the choice
  - Risks related to leaving out opportunity charging (charging at some stops), switching directly to battery electric buses (charged in the depot)
  - Possibility to recharge batteries during operation for technological and organisational reasons
  - Topography of the depot infrastructure
  - Possibility of having all the buses indoors over the night in order to keep batteries warm
  - High voltage access in depots and on terminal stops of established bus routes
- Strategy
  - Barriers, standing in the way of replacing conventional buses by electric buses
  - Points where one would benefit from the replacement of conventional buses by electric buses
  - Feeling of the pressure of local authorities aimed at persuading the exchange the existing bus fleets to electric buses
  - External funding and its types to support the process of conventional buses' conversion to electric
  - Favourites in terms of conversion strategy to 100% electric
  - Situations that will make a decision about exchanging one's bus fleet with electric buses
  - Time perspective at which the level of 100% electric-powered fleet will be reached
  - Scenarios of fleet replacement

- Criteria in the process of fleet conversion
- Activities related to the investment in electric buses the company intends to take in the next 24 months
- Co-operation with other entities to speed up the exchange of conventional bus fleet to electric one

- Economics
  - Amount of external funding for investments one need for taking the decision to replace the conventional bus fleet by an electric one
  - The planned sources for financing the replacement of conventional bus fleet with electric buses
  - Groups of expenses related to the process of conventional bus fleet conversion to electric buses
  - Kinds of procurement types
  - The influence of operating electric buses on fares (ticket prices)
  - Association of transition to electric buses with incurring additional operating costs
  - Changes in the employment structure due to the replacement of existing buses by electric ones
- PLATON Tool
  - Functionalities of an IT tool to support the planning of bus conversion process
  - Features of the PLATON tool

4.3 Questionnaire for authorities responsible for public transport in a city or urban region (conurbations)

The questionnaire addressed to authorities responsible for public transport in a city or urban region (conurbations) contains 32 questions, divided into 7 subjects:

- Organisational Scheme
  - Organisation of public transport
  - Role of the authority in organising public transport in a specific city/region
  - Support to be offered for converting to clean urban transport
  - Forms of supporting investments for replacing conventional bus fleet with electric-powered ones are provided by a governing body/legislator
  - An influence of the operation of electric buses on the patronage / ridership for public transport in the area being served

- The pressure of government or European institutions aimed at persuading the exchange the existing bus fleets to electric buses

- Available Data
  - Geographical data about trip relations of citizens
  - Data (position, speed over time) of the bus lines in the city/region
- Routes and Traffic Control
  - A chance for adapting established bus routes relocating stops for opportunity recharging
  - A possibility for shortening the bus routes, allowing lower investments for battery packs with opportunity charging
  - Traffic control at intersections (bus priority)
- Infrastructure
  - A structure of bus network
  - A structure of bus depot infrastructure
  - A possibility to adapt utility substations, if needed for fast recharging of buses
  - A possibility to adapt substations for trams or trolley buses so battery electric buses might be recharged too there swiftly
- Strategy
  - Favourites in terms of propulsion systems
  - Favourites in terms of conversion strategy to 100% electric
  - A possibility of using opportunity charging infrastructure (for buses) for charging cars and trucks
  - Risk related to leaving out opportunity charging (charging at some stops), switching directly to battery electric buses (charged in the depot)
  - Time perspective at which the level of 100% electric-powered fleet will be reached
  - Scenarios of fleet replacement
- Fleet conversion tool
  - Functionalities of an IT tool to support the planning of bus conversion process
  - Features of the PLATON tool
- Economics
  - Importance of external funding to support the process of conventional buses' conversion to electric buses

  - Amount of external funding for investments one need for taking the decision to replace the conventional bus fleet by an electric one
- Statistics – about your city/region
  - The share of public transport with regards to the trips
- Other Info
  - Name of the city/region, country, e-mail (optional fields)

5 Analysis of requirements of basic stages in transition to electric bus fleet

The term “battery electric bus” (the correct technical term is accumulator or secondary battery) includes dual mode trolley buses having batteries on board as well as electric buses with super capacitors or lithium capacitors or blends with secondary battery energy storage. An analysis of different approaches to problem of implementation of battery electric buses (BEBs) fleet shows that for decision any practical task from this sphere should be based on four typical stages presented below (Figure 5).

Stage 1 (Operational feasibility of different "bus & charging configurations" by routes) is necessary in order to highlight possible solutions in a system "BEBs fleet - Charging configuration". For this matter, the limitations of a particular route network (block “Characteristics & schedules of bus routes”) as well as the city electric network for example allowable voltages, locations of the charger positions (block “Power and accessibility of urban electric grid”), should be taken into account. A list of possible combinations of "bus models - charging technologies" is formed for each route (see 1. List ...). Typical specifications for buses and charging configurations accompany this list. As result every route receives some combinations “bus model & set of charging places” under possible charging configuration.

Stage 2 (Economic Analysis) includes three types of tasks with an increasing degree of complexity. The task 2.1 (Comparative analysis of variants) can be solved by considering the differences in the solutions being compared. The task 2.2 (TCO calculation / optimisation for BEBs fleet) requires consideration of the initial cost of buses and the cost of the charging infrastructure (block “Initial cost of BEBs & charging configuration”). A typical solution is the use of bank loans, leasing, etc. (block “Bank credit, leasing”). In some models, economic consequences on a city or country scale can be taken into account (for example, pollution penalties) (block “Pollutions: WTW (Well-to-Wheels) / TTW (Tank-to-Wheels)”]. Task 2.3: (TCO calculation / optimisation for BEBs & legacy bus fleets) provides for total cost of ownership (TCO) calculation taking into account the new fleet of electric buses and the operating fleet of buses (block "Legacy bus fleets"). This problem statement reflects the real situation and gives a comprehensive economic evaluation. The decommissioning or use of buses from the existing fleet can be reproduced. The TCO should be calculated for the entire system including in the general case of a mixed bus fleet and in time covering the transition period. Stage 3 (Development of business plan) provides for the development of a business plan, in which an economic part is required based on the results of the TCO analysis.

Stage 4 (Accompanying transition to electric bus fleet) is the process of accompanying the period of the introduction of the electric bus fleet. Well-known publications consider the perspective fleet of electric buses as a complete unchangeable system, to which the transition is to be carried out. An approach based on the concept of "open systems" should be developed. Under this concept the bus fleet is viewed as an open system, changing under the influence of external and internal factors and adapting to them. The system includes non-electric and electric buses. The task is reduced to ensuring the maximum efficiency of this system during the transition phase and the subsequent operation in a purely electric version. It is important to have the uniform understanding of the problem by stakeholders: bus manufacturers, legislators (authorities), municipalities and bus operators (operating organisations).

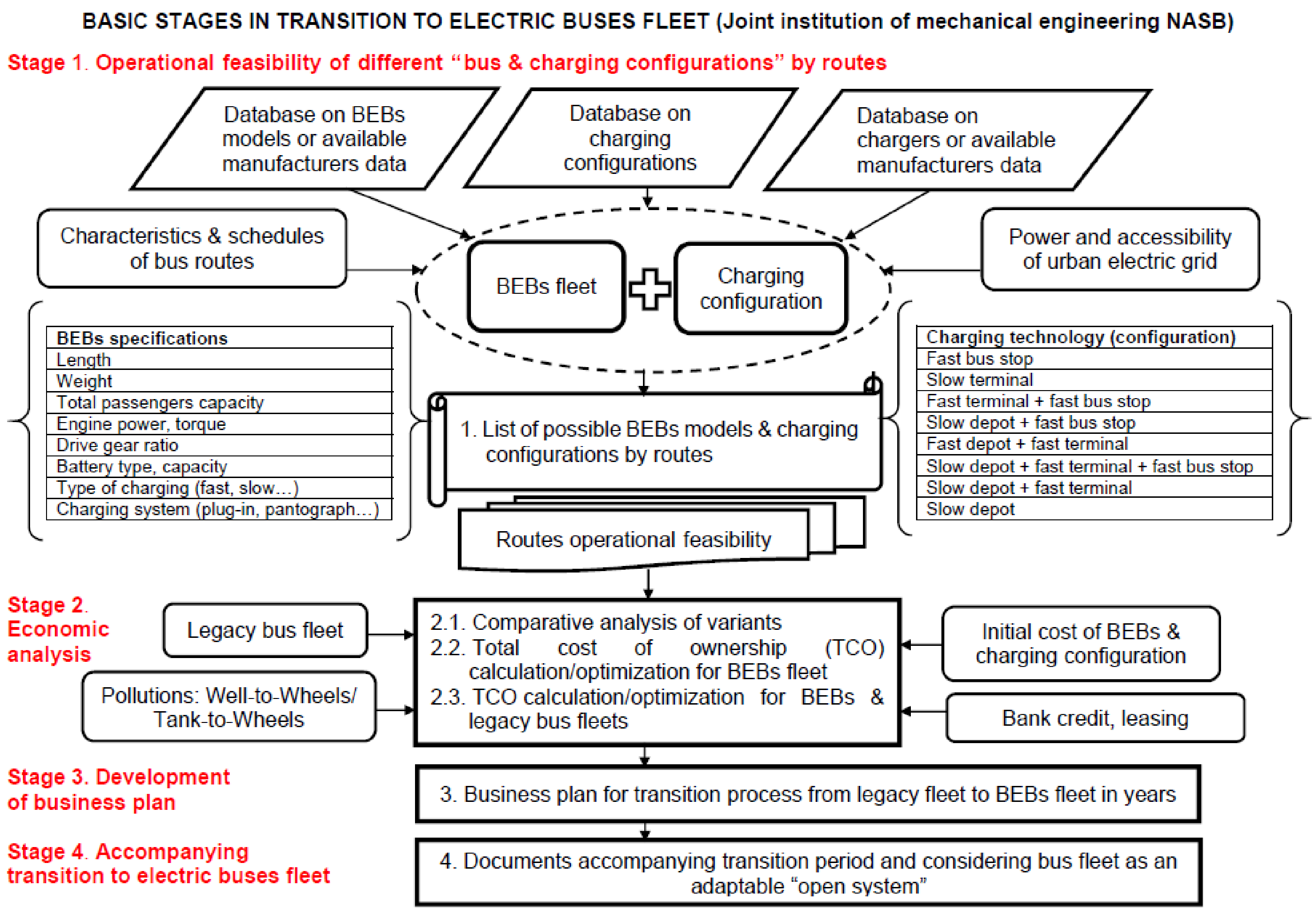

Figure 5. Basic stages in transition to electric buses fleet

6 Dependencies between domains and their entities for electric bus deployment

The diagram (Fig. 6) illustrates the dependencies between entities of various domains in the process of electric bus deployment. The dependencies describe the basic relationships between these entities in the form of edges, connecting nodes of the dependency network. Neighbouring nodes of the directed edges constitute a dependency. The input node of an edge has influence on the output node, or the output node is dependent on the input node. Nodes that have been considered as important for electric bus deployment are enriched by attributes. For example, a charging station has the property of a location in the road network and available charging technologies and power outlets.

The domains of the entities are the legislative and governmental domain, economic domain, public transport domain, the vehicle and fleet related domain and the domain of electric power generation and distribution grid. The nodes that belong to a domain are marked by similar colours. For example, the attributed and non-attributed nodes of the public transport domain are marked in red/light red. An affiliation of a node with a domain may be a subject of discussion. So, it is conceivable that the node of the corporate management of a transit company can belong to the domain of public transport or to the legislative and governmental domain. In the current view that was stimulated by governance aspects rather than immediate technological aspects, the node was assigned to the governmental domain. Public transit companies are in nearly all cases in 100% ownership by the local municipal government. Decisions made by the corporate management regarding procurement of e-buses require a close reconciliation with and endorsement by the local government.

The intensity of a dependency is indicated by the width of its edge. The relationships that are qualitatively more important and have a stronger influence are marked by a wider line. The different types of relationships are of various kinds and can usually not being described in analytical form. However, the dependencies have properties that can be described in order to improve understanding and characterise the relationship. For each of the indicated relations and combinations thereof, models can be built to describe further the relationships on macroscopic or microscopic level, in the theoretical area or practical-physical area, between different domains or within the same domain.

The models have input variables and output variables which can be numbers in the simplest form but also vectors of variables of various types, planning documents, procurement decisions and even also legal positions. The transfer performance of a relationship can be basically direct or inverse. A direct dependency is given if a quantitative increase of the input variables causes an increase of the output variables. An inverse dependency is given if a quantitative increase of the input variables causes a decrease of the output variable, and vice versa.

In the following paragraphs selected relationships are being described further, the numbers in brackets denote the numbers of edges that represent the dependencies.

Local government policies that are under legal and financial dependence of Federal and Provincial government policies (50) have an influence on urban development and land use (51). Urban development and planning of land use is under constitutional law a sovereign right of a local community, such as a city or a county. The result of the planning process is a zoning plan with map that describes and delineates the type and degree of structural use such as residential housing, industrial land uses or commercial land uses. (56)

The structure of zoning and housing has a strong influence (18) on transit demand that is met with public transit services (31). The planning process of public transit services comprises transit operations (33) and the design of the transit network (32). The latter one leads to a planning of transit stops (24) with locations that ensure a comfortable reachability and accessibility for the population of the residential areas as passengers of public transport services that influences the ridership (30) as occupation of buses in revenue service. Bus stops are connected by a (transit) route (24). The route geometry depends on the location of its stops. There should be a reasonable connection, a feasible/driveable connection which is not necessarily the shortest path between two stops. The higher the ridership the higher the frequency (57) of transport vehicles with a given size has to be planned which constitutes a direct dependency (correlation to seat-km offered). A higher frequency of vehicle in connection with a shorter headway (36) requires for more vehicles to be scheduled in the timetable, resulting in the need for a higher required quantity of electric buses (3).

The corporate management of a transit company will draw decisions on procurement of electric buses based on entrustment of transit services (16) and provisions of funding (17) both provided by local government policies, (53) and (52) respectively, that are being executed on the basis of parliamentary resolutions. Furtherly, the corporate management takes into consideration strategical alternatives and decisions on tram extension or e-bus transition that have been drawn on a long-term basis. The procurement decision for e-buses is based on economic feasibility studies that include the procurement cost (12) and operational costs to be determined by costs of ownership (13) and cost of charging infrastructure (14). Costs of ownership depend on depreciation determined by bus life span (46) maintenance cost (11), determined by workshop costs (45) and personnel costs that are determined by the wage level (44) in the respective country. The corporate operational costs accounting process taking into account municipal subsidies results in fare calculations (15). The amount of fares have an inverse proportional impact on the transit share within the model split breakdown of transport mode choices of the traffic and transport user. High fares will lead to lower the transit share, low fares will lead to a higher transit share. A lower transit share itself will decrease the transit demand (19) and vice versa.

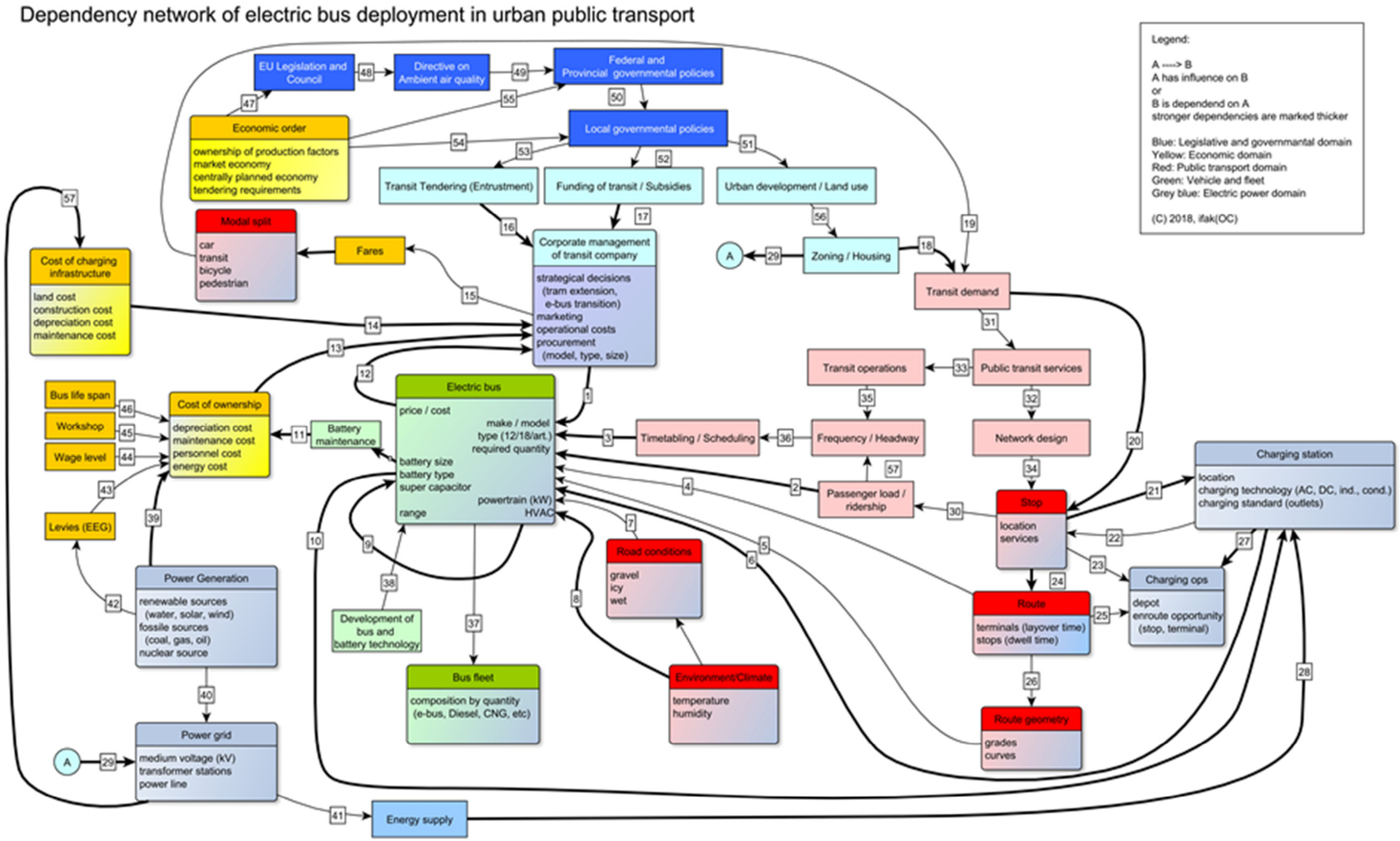

Figure 6. Dependency network of electric bus deployment in urban public transport

Not to be underestimated are the energy costs that are determined by costs of power generation (39) that are composed of power generation sources of lower cost categories (water, coal, nuclear) and higher cost categories (solar, wind, gas, oil) and levies (43) charged for the allocation of significant costs for renewable energy production (42). An important precondition for the construction of charging infrastructure is the spatial proximity to power lines of medium voltage (40) 1 kV up to 30 kV to supply enough energy (41) for charging stations. So, the location of charging stations is influenced by both the location of bus stops (21) and by the proximity to energy supply (28). The availability of transformer stations from medium voltage to low voltage is essential for the cost of charging infrastructure (57). Eventually new transformer stations and additional cabling to charging stations have to be build adding up to any-way-cost-figures.

For different models that are developed to describe the relations and dependencies it must be assured, that interoperability is ensured in terms of data models and interfaces for input/output data exchange.

7 Summary

The result of this part of the PLATON project works are the guidelines for STEEP analysis, as a result of which presumptions have been defined for the assumptions for the fleet conversion model. As a part of the above mentioned process approach were identified the most important factors that influence the fleet conversion process to be taken into account in the final product (PLATON Tool). We presented the motivations and hindering arguments for bus fleet transition as well as the basic stages in fleet transition to electric fleet, which will be evaluating towards the descriptive character. Three questionnaires for three stakeholders:

- Producers of public transport buses with electric power trains
- Operators of public transport buses with electric power trains
- Authorities responsible for public transport in a city or urban region (conurbations)

have been developed and will be distributed among associated partners and other dedicated recipients. The deliverable is concluded by the analysis of the dependency network of related domains and their entities in the complex framework of electric bus deployment.