Algorithmization of Transport Analyzes for Urban Areas – Concept and Case Studies

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Agenda

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3. **Main Conditions for the Process of Algorithmization of Transport Analyzes for Urban Areas**
4. **Main assumptions of the Methodology with the use of Systems Engineering**
5. **Main Assumptions of the Transport Project Formalization**
6. **Main Block Diagram (Algorithm) of Transport Analyzes for Urban Areas**
7. **Structure of Data Sources**
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Abstract:

The presentation includes the concept of algorithmization and main algorithm of the process of creating transport analyzes for urban areas.

The need to develop the algorithmization proces and main algorithm results from the formation of key elements of transport analyzes as well as new possibilities of obtaining data describing both transport processes and urbanization processes.

Algorithmization covers the various stages of creating a transport analysis in a systemic perspective.

The presented concept uses systems engineering methods adapted to the specifics of the description of transport systems and processes in urban areas.

Keywords: algorithmization process; transport analyzes; transport modelling, urban areas

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Introduction

- The **Main Goal** of the study is to present the **Key Factors** shaping the **Process of Algorithmization of Transport Analyzes for Urban Areas.**

Algorithmization

- ✓ Process of convertion an informal description of a process or a procedure into an **Algorithm**.

Algorithm

- ✓ Informally, an algorithm is any well-defined computational procedure that takes some value, or set of values, as input and produces some value, or set of values, as output.
- ✓ An algorithm is thus a sequence of computational steps that transform the input into the output (**1990**, Cormen, Leiserson, and Rivest, *Introduction to Algorithms*: page 1. Cambridge, MA, The MIT Press, 1999 (*23rd printing*)).

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Introduction

- The **Main Goal** of the study is to present the **Key Factors** shaping the **Process of Algorithmization** of **Transport Analyzes for Urban Areas.**

In the case of **Transport Analyzes for Urban Areas**
Algorithmization is the **process** of transforming the informal description
of the **Transport Project**
and the **Mathematical Modeling of Transport Systems and Processes**,
treated of course as a methodology, into an **algorithm**.

In the A**lgorithmization Process** presented in this study, a **new approach** was used to represent the **Transport Project** in the **Mathematical Modeling of Transport Systems and Processes**.

Introduction

- The **new approach** in the presented algorithmization process is the distinction in the formal description of the Transport Project, the so-called **Functional-Operational Configuration of Tasks in a Transport Project** (FOCT), which includes:
  - set of task in the field of Mobility Management,
  - set of task in the field of Intelligent Transport Systems,
  - set of task in the field of Other Transport Services.

The distinction of these three sets of tasks is for the purpose of preliminary domain classification for **detailed interdisciplinary methods** of transport project modeling in these three areas.

The result of transport analysis to solving transport problems using an **appropriate algorithm** is the selection of **Activities** and T**asks** and the creation of the **Set of Variants of Task Configuration - VFOCT**.

VFOCT includes variants, which are then subject to **Multi-criteria Assessment**, e.g. according to known criteria: efficiency, cost, time, resources, stakeholder aspirations, etc.

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Introduction

- The presented issues of Transport Analyzes with **Functional-Operational Configuration of Tasks in a Transport Project** (FOCT) are **multidisciplinary**, so this new approach is just in order to use

  Systems Engineering Methods in the **Algorithmization Process for Transport Analyzes for Urban Areas.**

  This approach emphasizes the need for a **holistic approach** when creating **Transport Projects**, which is often forgotten in practical transport analyzes.

  The **holistic approach** in this case concerns taking into account the **multidisciplinary interdependencies** between:

  - description of **transport systems**
  - description of **urban areas**
  - description of **activity of residents**
  - description of **transport needs**
  - and the **use of adequately accurate:**
    - **models**
    - **methods**
    - **tools**

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Introduction

- This approach highlights the need to use **Systems Engineering Methods** in the algorimization proces with **Functional-Operational Configuration of Tasks in Transport Project (FOCT).**

Systems Engineering is a **transdisciplinary** and **integrative approach** to enable the successful realization, use, and retirement of engineered systems, using **systems principles and concepts, and scientific, technological, and management methods**.
(*The International Council on Systems Engineering (INCOSE)*)

Such a **system approach** makes it possible to take into account interdisciplinary issues and **forces the involvement of a multidisciplinary design team**, which improves the **quality of the transport project** and **its variants**.

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Introduction

- This approach **improves the Algorithmization Process**, the result of which will be the target **Algorithm** – more precisely, **several detailed algorithms** that are still in the development phase and will be partial algorithms within the **Main Algorithm of Transport Analyzes for Urban Areas**.

The form of presentation of the content on the next slides also corresponds to the process of **Formalization and Algorithmization**, because the graphic was used to present the important issues in the form of problem blocks and the links between them

➔ It is an element of the algorithmization process, i.e. "convertion an informal description of a process or a procedure into an algorithm".

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Main Conditions
for the Process of Algorithmization
of Transport Analyzes for Urban Areas

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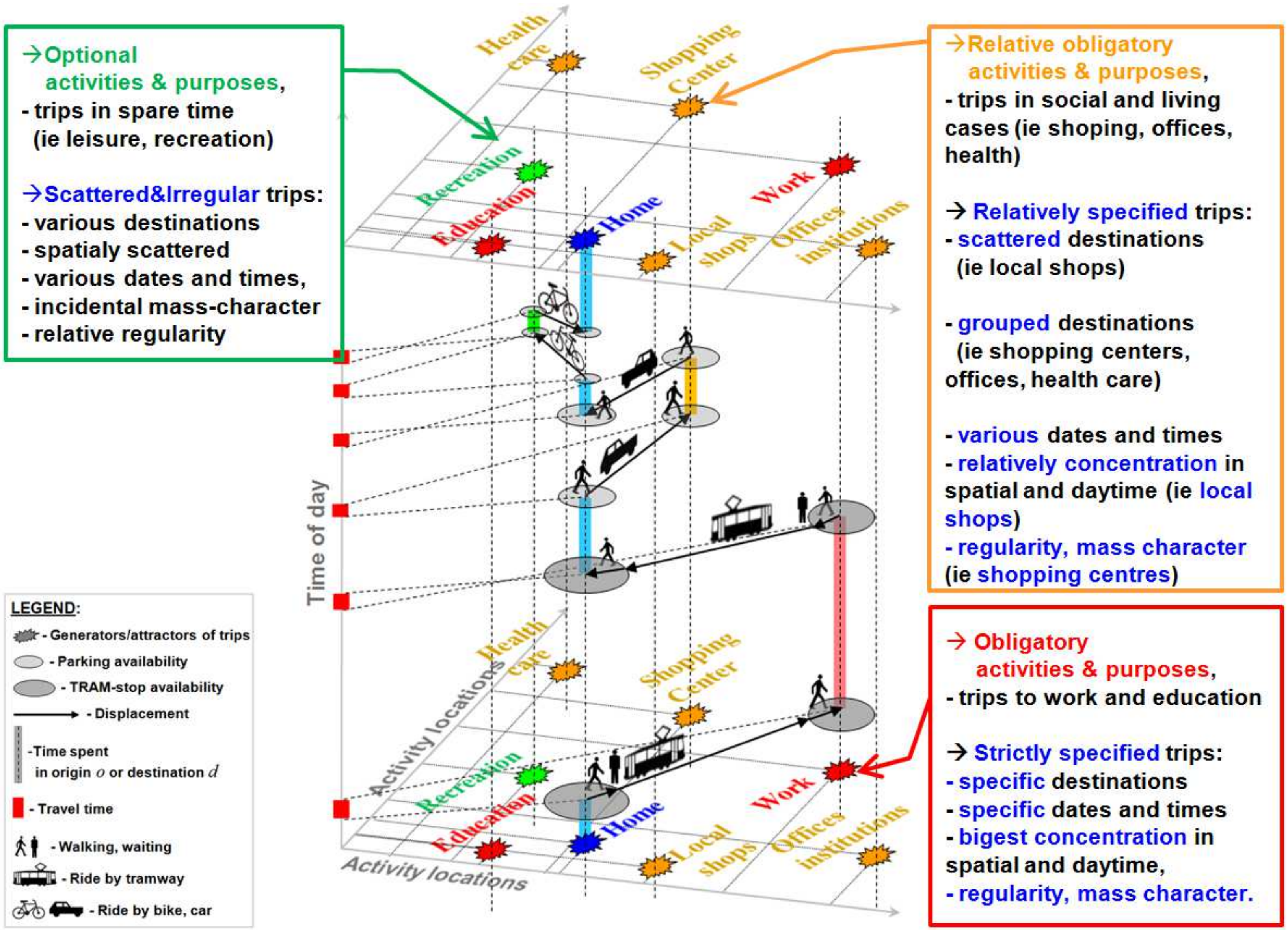
Dynamic Relationships Between
the Urban Area and the Transport System – aspects of Demand Traffic for Transport System



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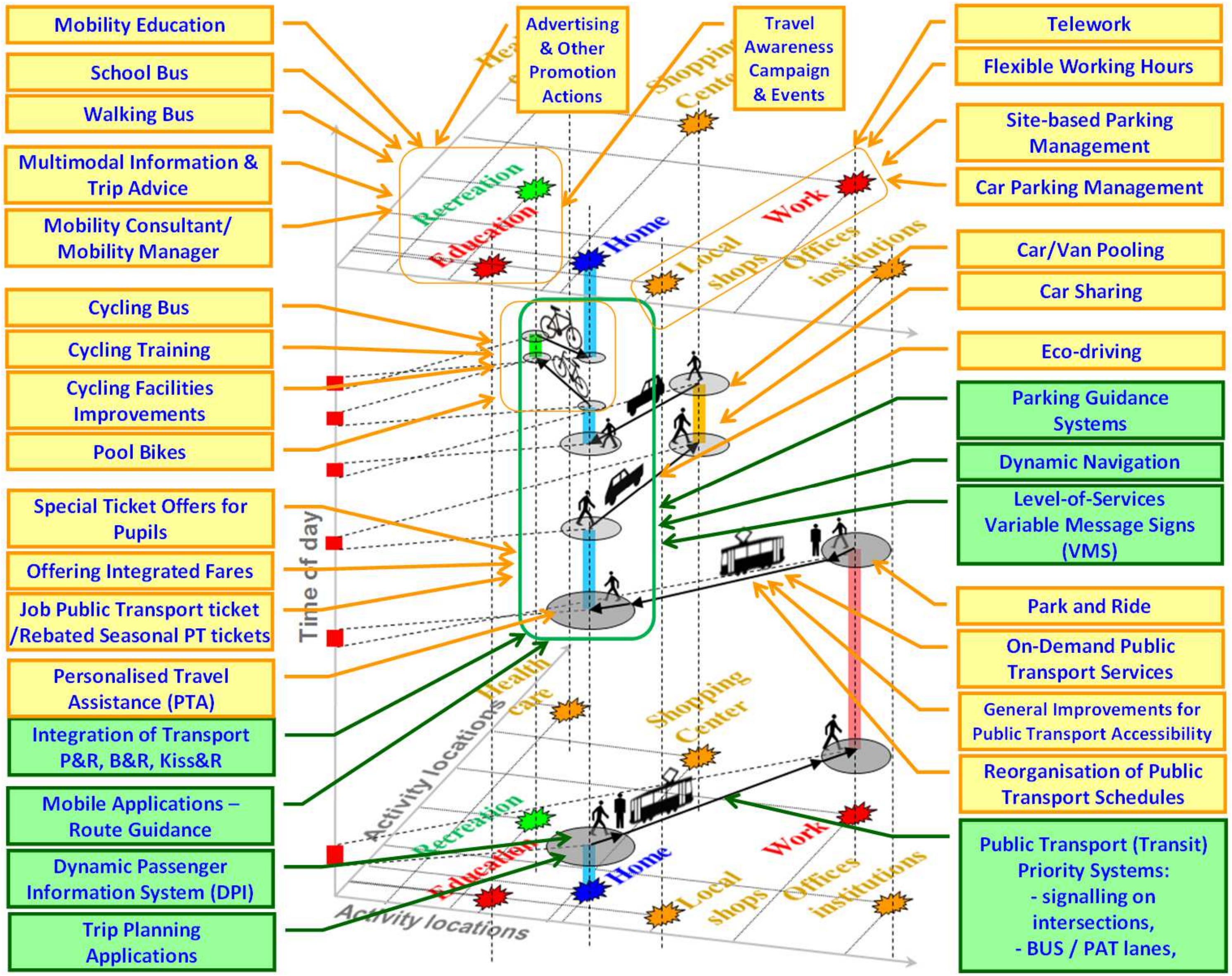
Dynamic Relationships Between the Urban Area and the Transport System – aspects of Actions, Tasks and Services of Transportation Systems



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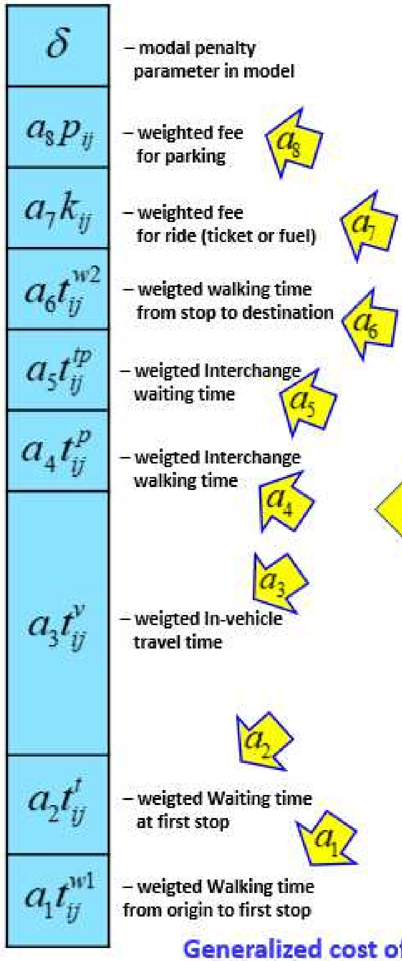
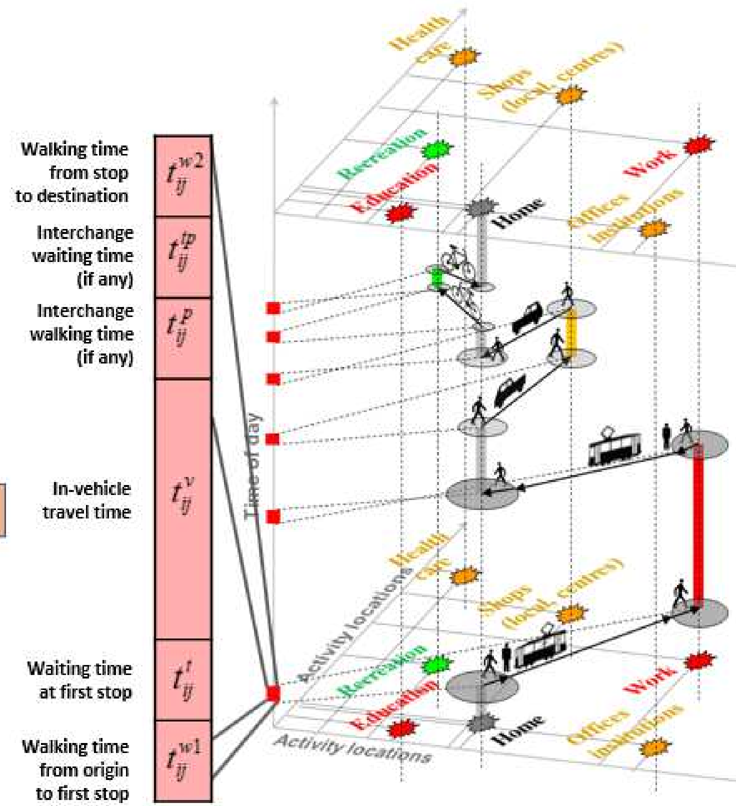


Transport Project Functional and Physical Configuration



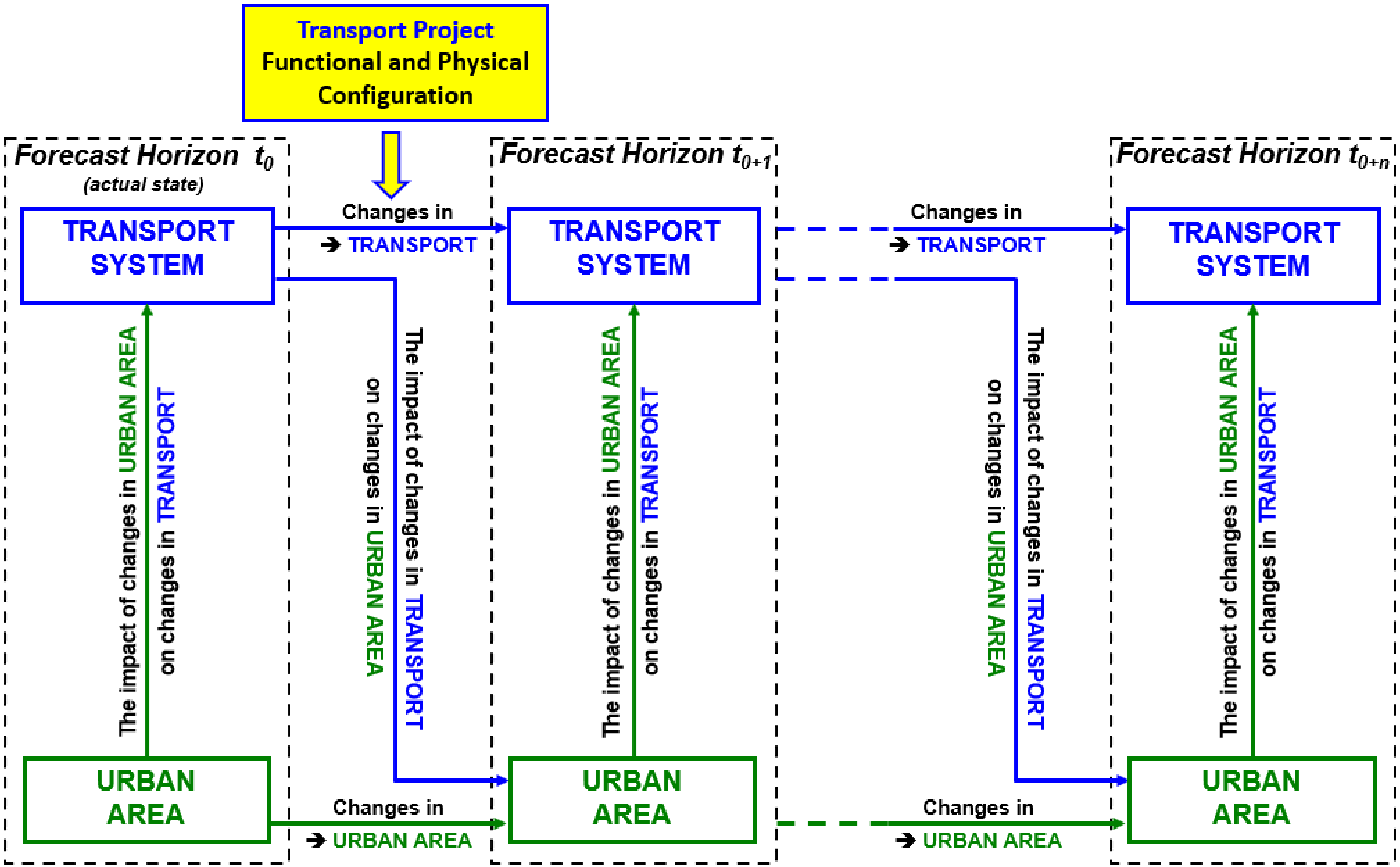
Generalized cost of travel c_{ij} between origin i and destination j

$$c_{ij} = a_1 t_{ij}^{w1} + a_2 t_{ij}^{t} + a_3 t_{ij}^{v} + a_4 t_{ij}^{p} + a_5 t_{ij}^{tp} + a_6 t_{ij}^{w2} + a_7 k_{ij} + a_8 p_{ij} + a_8 \delta$$

Travel time t_{ij} between origin i and destination j

$$t_{ij} = t_{ij}^{w1} + t_{ij}^{t} + t_{ij}^{v} + t_{ij}^{p} + t_{ij}^{tp} + t_{ij}^{w2}$$

Dynamic Relationships Between the Urban Area and the Transport System – aspects of Changes and Forecasts



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Main assumptions of the Methodology with the use of Systems Engineering

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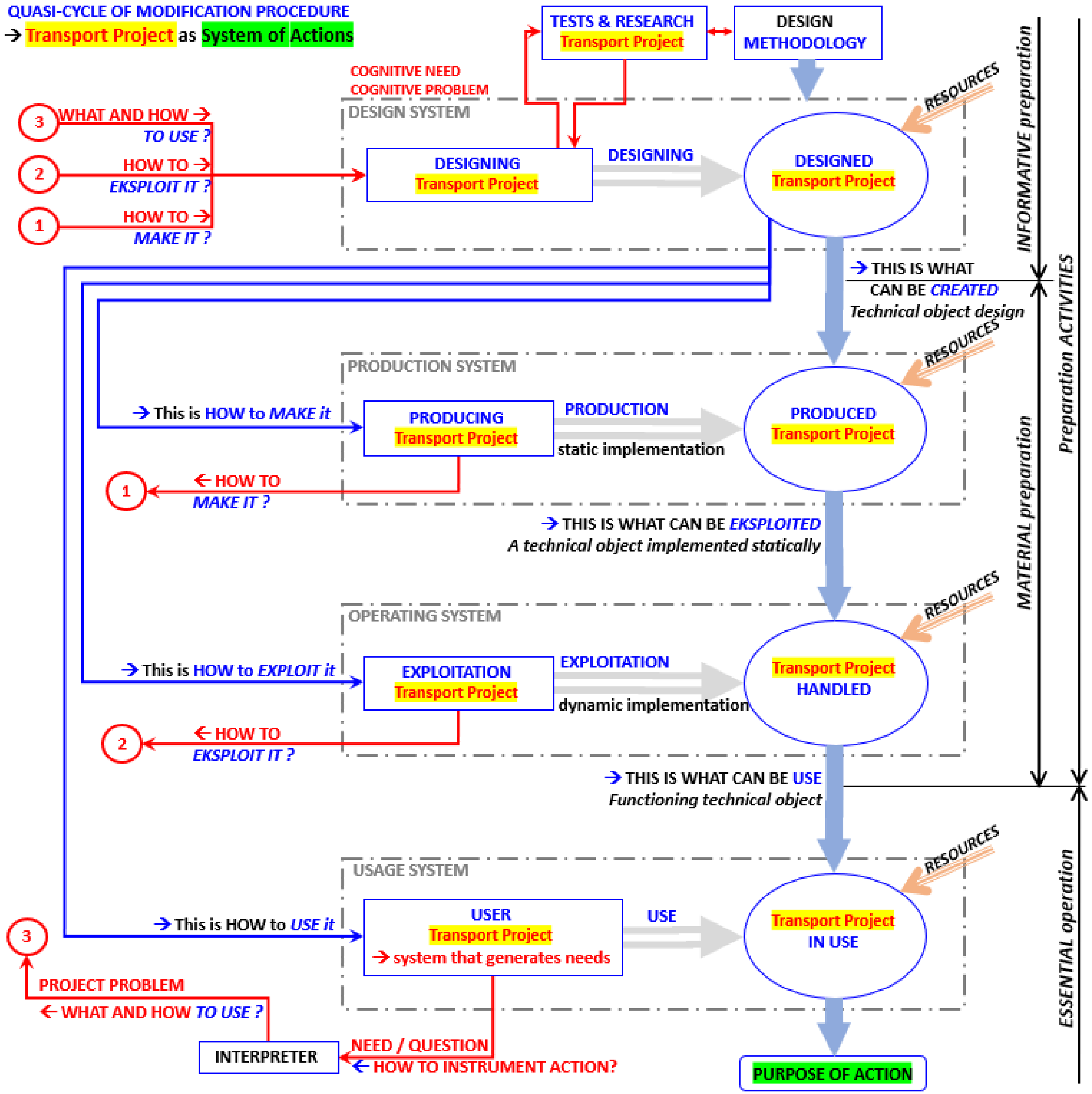
Main Assumptions of the Methodology with the use of Systems Engineering



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Main Assumptions of the Transport Project
Formalization

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Functional-Operational Configuration of Tasks in Transport Project (FOCT) will be determined as follows:

- set of **Tasks** in the field of **Mobility Management** (mobility management as services) – $\boldsymbol{ToMM}$,

- a set of **Tasks** in the field of traffic control and management using **Intelligent Transport Systems** (ITS services) – $\boldsymbol{ToITS}$,

- a set of other **Tasks** in transport activities – related to improvement in the field of **Other Transport Services**, which include, among others with the modernization and development of infrastructure and means of transport (transport services) – $\boldsymbol{ToOTS}$.

Individual tasks within each of these collections have been numbered accordingly. Therefore, **sets of task numbers** can be represented as:

$$\boldsymbol{ToMM} = \{0,1,\dots,to\_mm,\dots,\overline{ToMM}\}, \tag{1}$$
$$\boldsymbol{ToITS} = \{0,1,\dots,to\_its,\dots,\overline{ToITS}\}, \tag{2}$$
$$\boldsymbol{ToOTS} = \{0,1,\dots,to\_ots,\dots,\overline{ToOTS}\}, \tag{3}$$

where:

$\overline{ToMM}, \overline{ToITS}, \overline{ToOTS}$ – numbers of tasks in sets respectively: $\boldsymbol{ToMM}, \boldsymbol{ToITS}, \boldsymbol{ToOTS}$.

At the same time, it was assumed that $to\_mm = 0$, $to\_its = 0$, $to\_ots = 0$ means that no tasks from the specified sets are used.

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Within the mentioned sets it is possible to indicate **partial task configurations**, which can be mapped specified **subsets**:

$\boldsymbol{CToMM}$, $\boldsymbol{CToITS}$, $\boldsymbol{CToOTS}$ of the sets: $\boldsymbol{ToMM}$, $\boldsymbol{ToITS}$, $\boldsymbol{ToOTS}$, respectively:

$$\boldsymbol{CToMM}(c\_mm) \subset \boldsymbol{ToMM}, \tag{4}$$

$$\boldsymbol{CToITS}(c\_its) \subset \boldsymbol{ToITS}, \tag{5}$$

$$\boldsymbol{CToOTS}(c\_ots) \subset \boldsymbol{ToOTS}, \tag{6}$$

$$\boldsymbol{CToMM} = \{\boldsymbol{CToMM}(c\_mm):\ \ c\_mm \in \boldsymbol{C\_MM}\}, \tag{7}$$

$$\boldsymbol{CToITS} = \{\boldsymbol{CToITS}(c\_its):\ \ c\_its \in \boldsymbol{C\_ITS}\} \tag{8}$$

$$\boldsymbol{CToOTS} = \{\boldsymbol{CToOTS}(c\_ots):\ \ c\_ots \in \boldsymbol{C\_OTS}\} \tag{9}$$

where:

c_mm, c_its, c_ots – task configuration numbers,

$\boldsymbol{C\_MM}$, $\boldsymbol{C\_ITS}$, $\boldsymbol{C\_OTS}$ – sets of configuration numbers.

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For each subset of the task configurations: $\boldsymbol{CToMM}$, $\boldsymbol{CToITS}$, $\boldsymbol{CToOTS}$ the **characteristics** of these configurations are specified, including among others **characteristics** of **individual tasks** that are part of the configuration: **start date**, **duration**, end **date**, **priority** and **order** of tasks, **necessary resources** (time, personnel, financial, etc.).

The number of **functions describing these characteristics** for each group of tasks may be different because it depends on the complexity and type of tasks.

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Therefore, it was assumed that on sets: $\boldsymbol{CToMM}$, $\boldsymbol{CToITS}$, $\boldsymbol{CToOTS}$ mapping transforming elements of these sets into a set of real numbers is given as follows:

$$fctomm^{ifctomm}\colon \boldsymbol{CToMM} \to \mathbb{R},\ ifctomm = 1, \dots \overline{IFCToMM}, \tag{10}$$
$$fctoits^{ifctoits}\colon \boldsymbol{CToITS} \to \mathbb{R},\ ifctoits = 1, \dots \overline{IFCToITS}, \tag{11}$$
$$fctoots^{ifctoots}\colon \boldsymbol{CToOTS} \to \mathbb{R},\ ifctoots = 1, \dots \overline{IFCToOTS}, \tag{12}$$

where:

$\overline{IFCToMM}$, $\overline{IFCToITS}$, $\overline{IFCToITS}$ – numbers of elements in sets respectively: $\boldsymbol{IFCToMM}$, $\boldsymbol{IFCToITS}$, $\boldsymbol{IFCTo\_OTS}$; these sets contain numbers of various functions (with different interpretations) specified on the sets, respectively: $\boldsymbol{CToMM}$, $\boldsymbol{CToITS}$, $\boldsymbol{CToOTS}$,

$fctomm^{ifctomm}\big(\boldsymbol{CToMM}(c\_mm)\big) \in \mathbb{R}$, $fctoits^{ifctoits}\big(\boldsymbol{CToITS}(c\_its)\big) \in \mathbb{R}$, $fctoots^{ifctoots}\big(\boldsymbol{CToOTS}(c\_ots)\big) \in \mathbb{R}$ – should be interpreted as the function values of the following types, respectively: $ifctomm$, $ifctoits$, $ifctoots$ for task configuration numbers, respectively: (c_mm), (c_its), (c_ots).

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The values of functions specified for individual sets of task configurations can be presented in the form of the following matrices:

$$\boldsymbol{FCToMM} = \left[\begin{matrix} fctomm^{ifctomm}\left(\boldsymbol{CToMM}(c\_mm)\right):\ \boldsymbol{CToMM}(c\_mm) \in \boldsymbol{CToMM}, \\ c\_mm \in \boldsymbol{C\_MM},\ \ ifctomm = 1, \dots \overline{IFCToMM} \end{matrix} \right] \quad (13)$$

$$\boldsymbol{FCToITS} = \left[\begin{matrix} fctoits^{ifctoits}\left(\boldsymbol{CToITS}(c\_its)\right):\ \boldsymbol{CToITS}(c\_its) \in \boldsymbol{CToITS}, \\ c\_its \in \boldsymbol{C\_ITS},\ \ ifctoits = 1, \dots \overline{IFCToITS} \end{matrix} \right] \quad (14)$$

$$\boldsymbol{FCToOTS} = \left[\begin{matrix} fctoots^{ifctoots}\left(\boldsymbol{CToOTS}(c\_ots)\right):\ \boldsymbol{CToOTS}(c\_ots) \in \boldsymbol{CToOTS}, \\ c\_ots \in \boldsymbol{C\_OTS},\ \ ifctoots = 1, \dots \overline{IFCToOTS} \end{matrix} \right] \quad (15)$$

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The set of all functions describing all characteristics for all analyzed task configurations can be written as **Functional-Operational Configuration of Tasks in Transport Project**:

$$\boldsymbol{FOCT} = \boldsymbol{FCToMM} \cup \boldsymbol{FCToITS} \cup \boldsymbol{FCToOTS} \qquad (16)$$

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By comparing individual configurations from the presented sets of tasks, it is possible to build various variants of task configuration.

Therefore, variants of task configuration can be numbered and compiled as a set:

$$\boldsymbol{VFOCT} = \{VFOCT(ivfoct):\quad ivfoct = 1, \dots, \overline{IVOCT}\}, \qquad (17)$$

where:

$ivfoct$ is the task configuration variant number, and $\overline{IVOCT}$ indicates the number of elements of the set $\boldsymbol{IVOCT}$, that contains the numbers of different variants.

A **single** $ivfoct$-th **task configuration variant** can be presented as:

$$\begin{gathered} VFOCT(ivfoct) = \left(\boldsymbol{CToMM}(c\_mm), \boldsymbol{CToITS}(c\_its), \boldsymbol{CToOTS}(c\_ots)\right): \\ \boldsymbol{CToMM}(c\_mm) \in \boldsymbol{CToMM},\quad \boldsymbol{CToITS}(c\_its) \in \boldsymbol{CToITS}, \\ \boldsymbol{CToOTS}(c\_ots) \in \boldsymbol{CToOTS},\quad c\_mm \in \boldsymbol{C\_MM}, \\ c\_its \in \boldsymbol{C\_ITS},\quad c\_ots \in \boldsymbol{C\_OTS}, \\ ivfoct = 1, \dots, \overline{IVOCT} \end{gathered} \qquad (18)$$

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Main Block Diagram (Algorithm) of Transport Analyzes for Urban Areas

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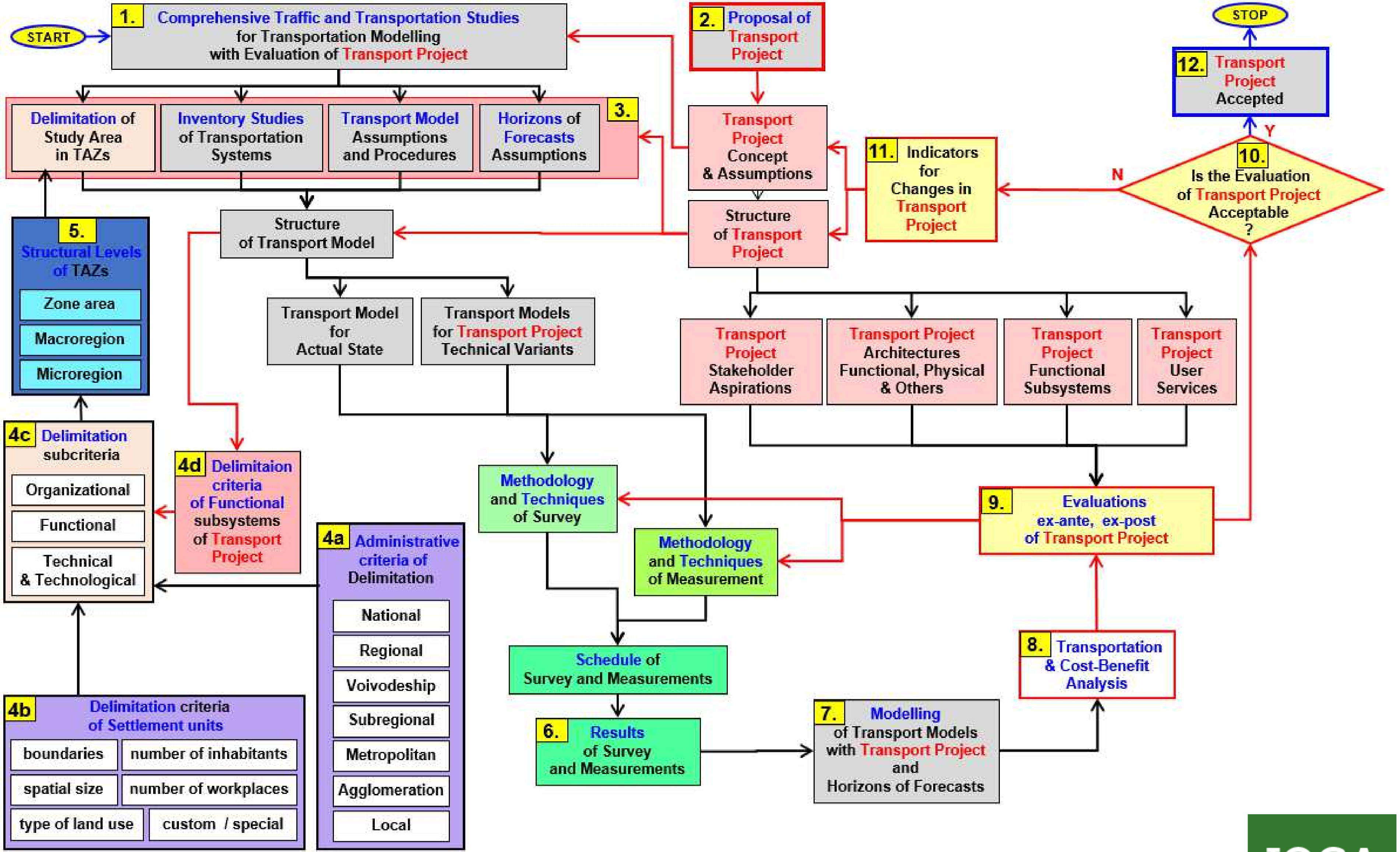
Main Block Diagram (Algorithm)
of Transport Analyzes for Urban Areas



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Structure of Data Sources

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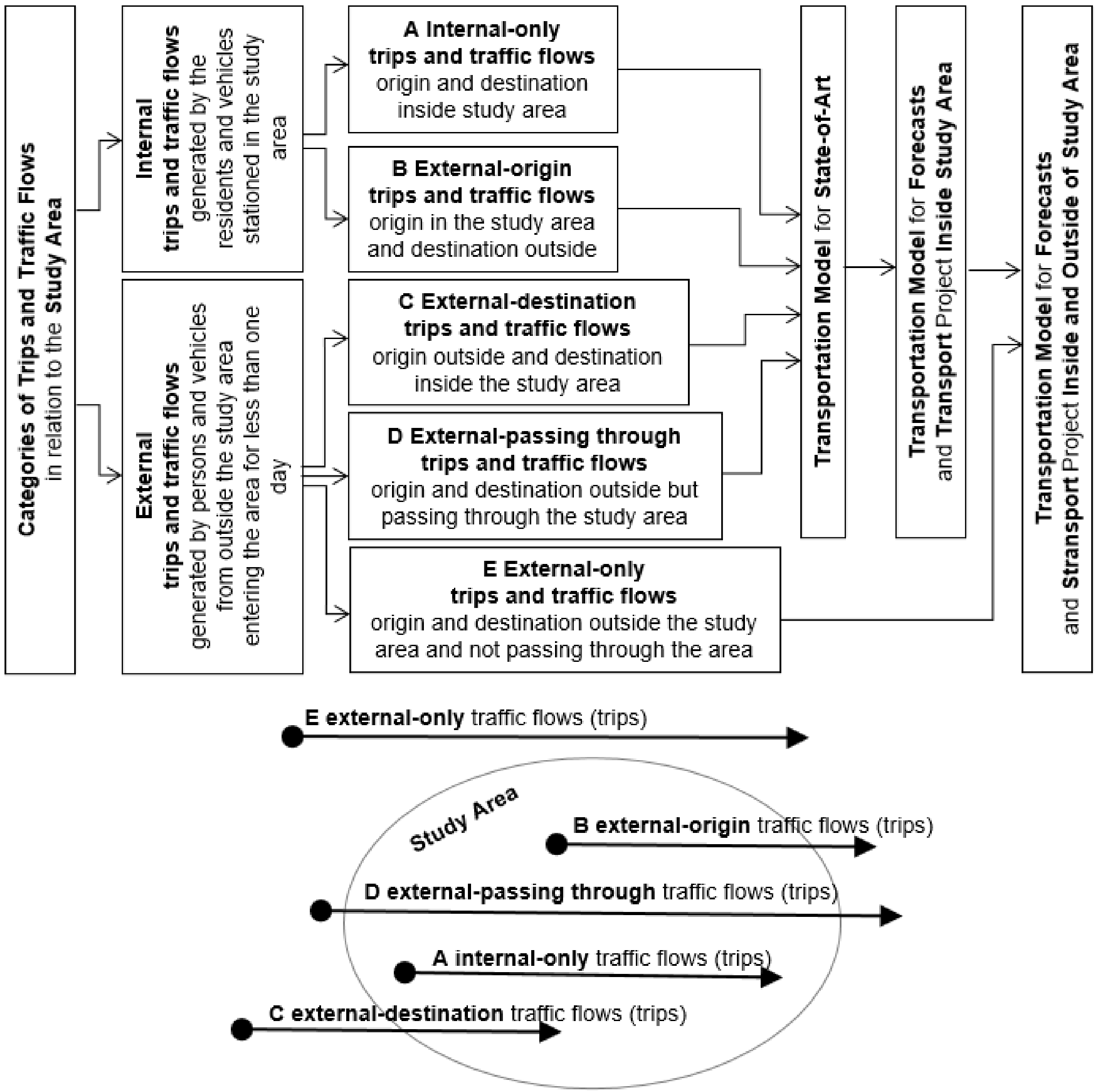
Structure of Data Sources – Categories of Trips and Traffic Flows in Relation to the Urban Area



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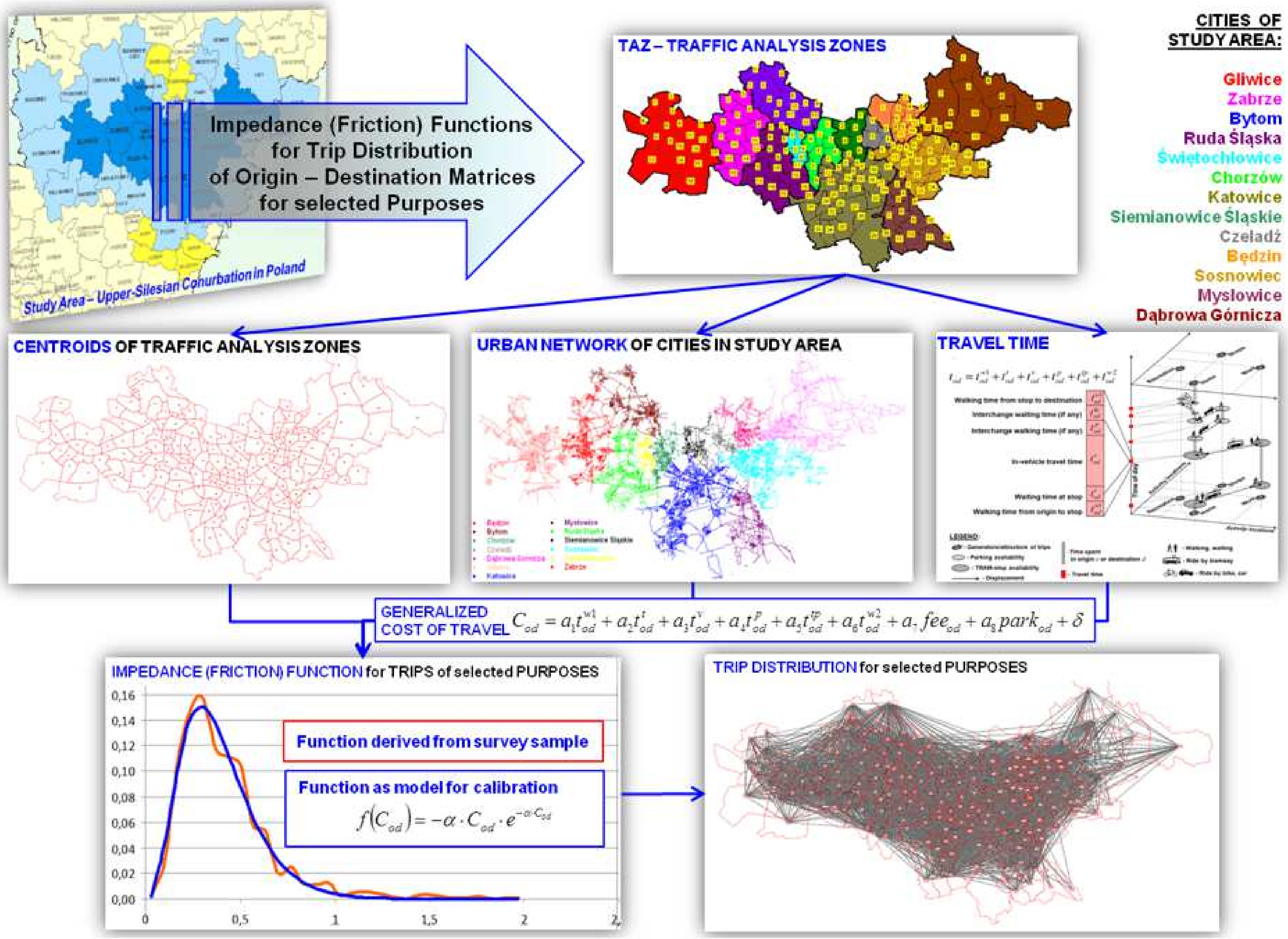
Case Studies
– Selected Components of Transport Analyzes

Case studies – Example of Impedance Function Modeling for Upper-Silesia Urban Agglomeration in Poland



Source: based on ***Karoń G.: Travel Demand and Transportation Supply Modeling for Agglomeration withoutt Transportation Model.***
In J. Mikulski (Ed.): Activities of Transport Telematics, CCIS 395, pp. 284-293, Springer-Verlag Berlin Heidelberg 2013.

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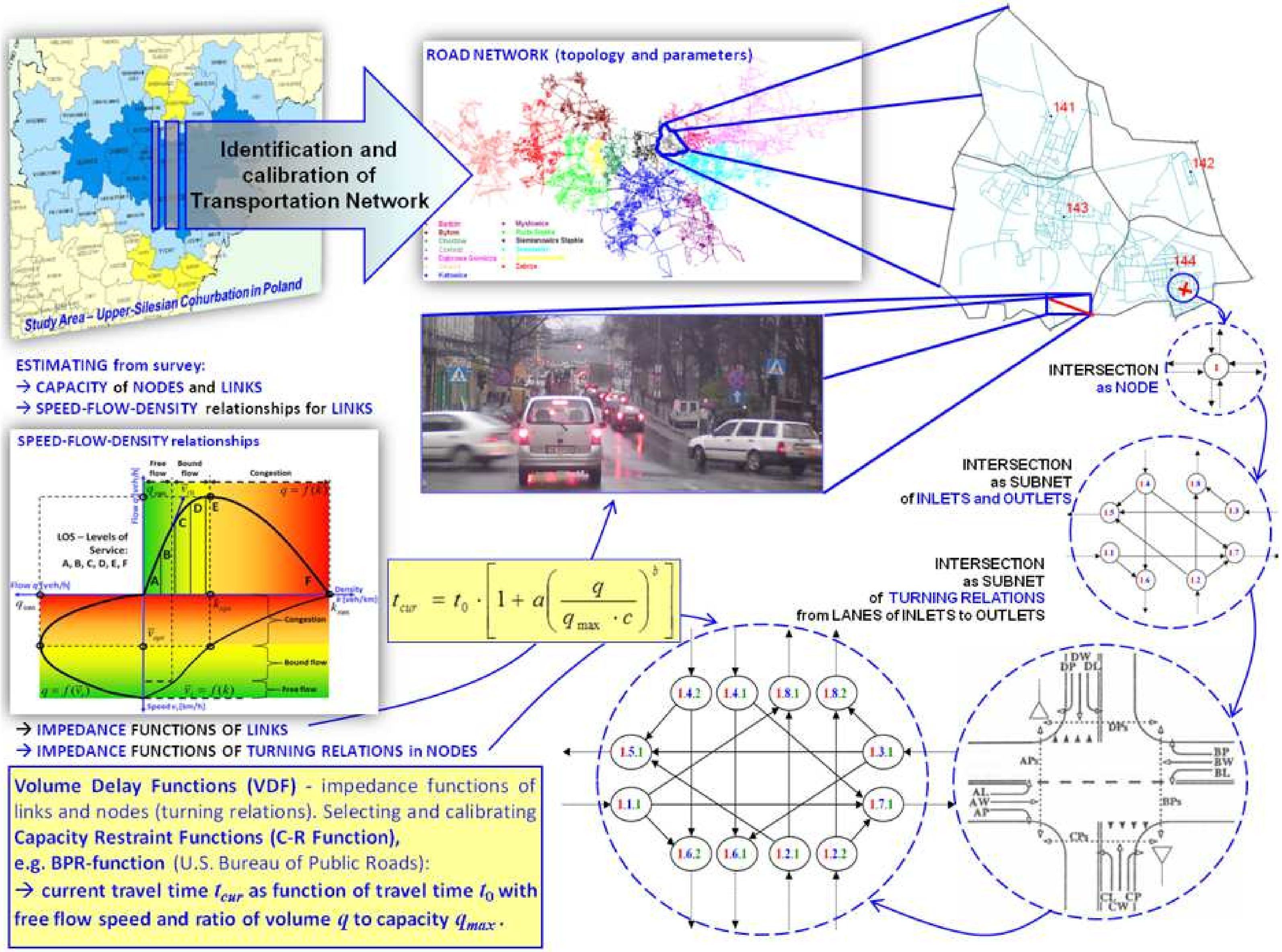
Case studies – Example of Volume Delay Function Modeling for Upper-Silesia Urban Agglomeration in Poland



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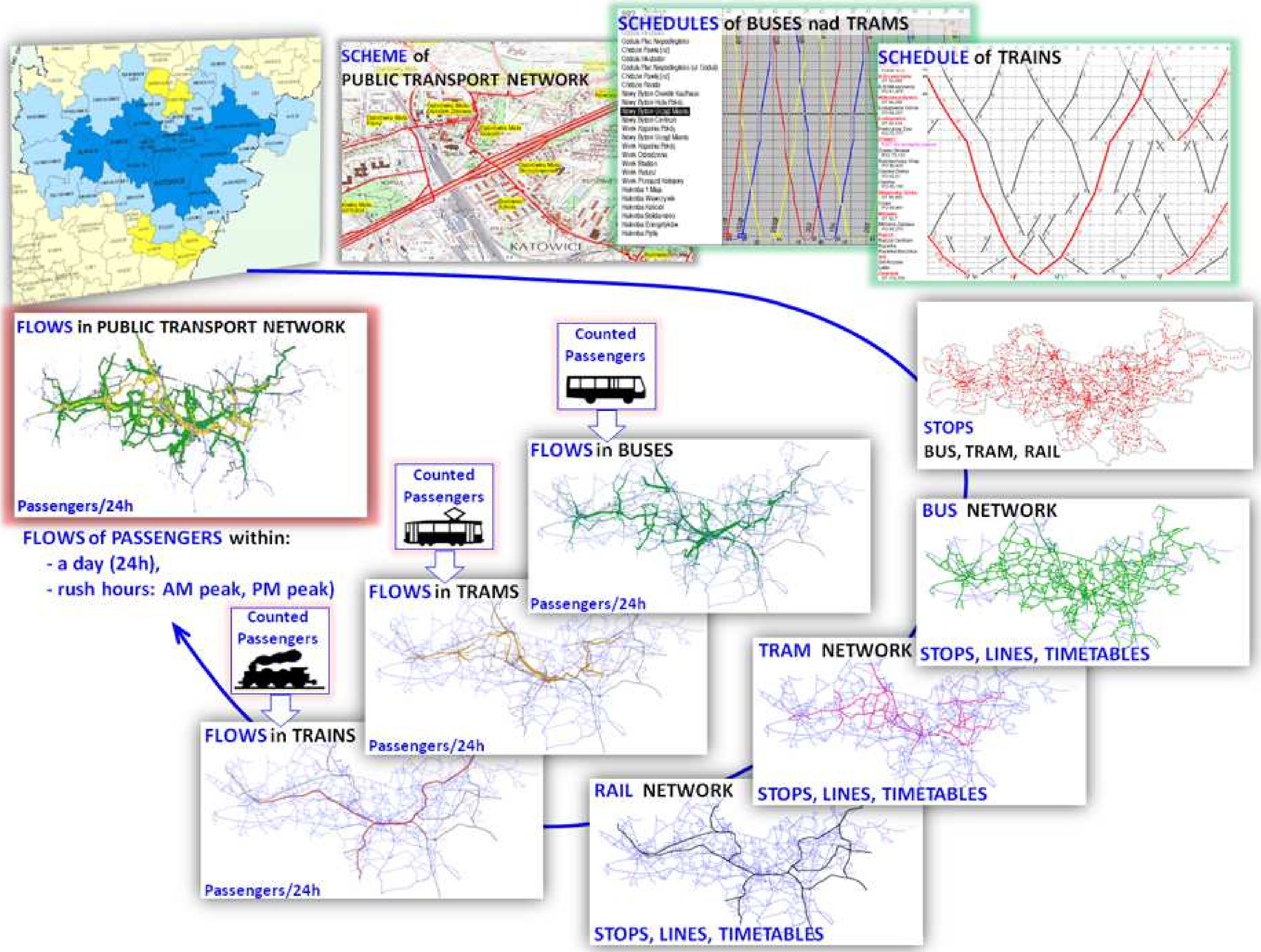
Case studies – Example of Public Transport Services Modeling for Upper-Silesia Urban Agglomeration in Poland



Source: based on **Karoń G.: *Travel Demand and Transportation Supply Modeling for Agglomeration withoutt Transportation Model.*** *In J. Mikulski (Ed.): Activities of Transport Telematics, CCIS 395, pp. 284-293, Springer-Verlag Berlin Heidelberg 2013.*

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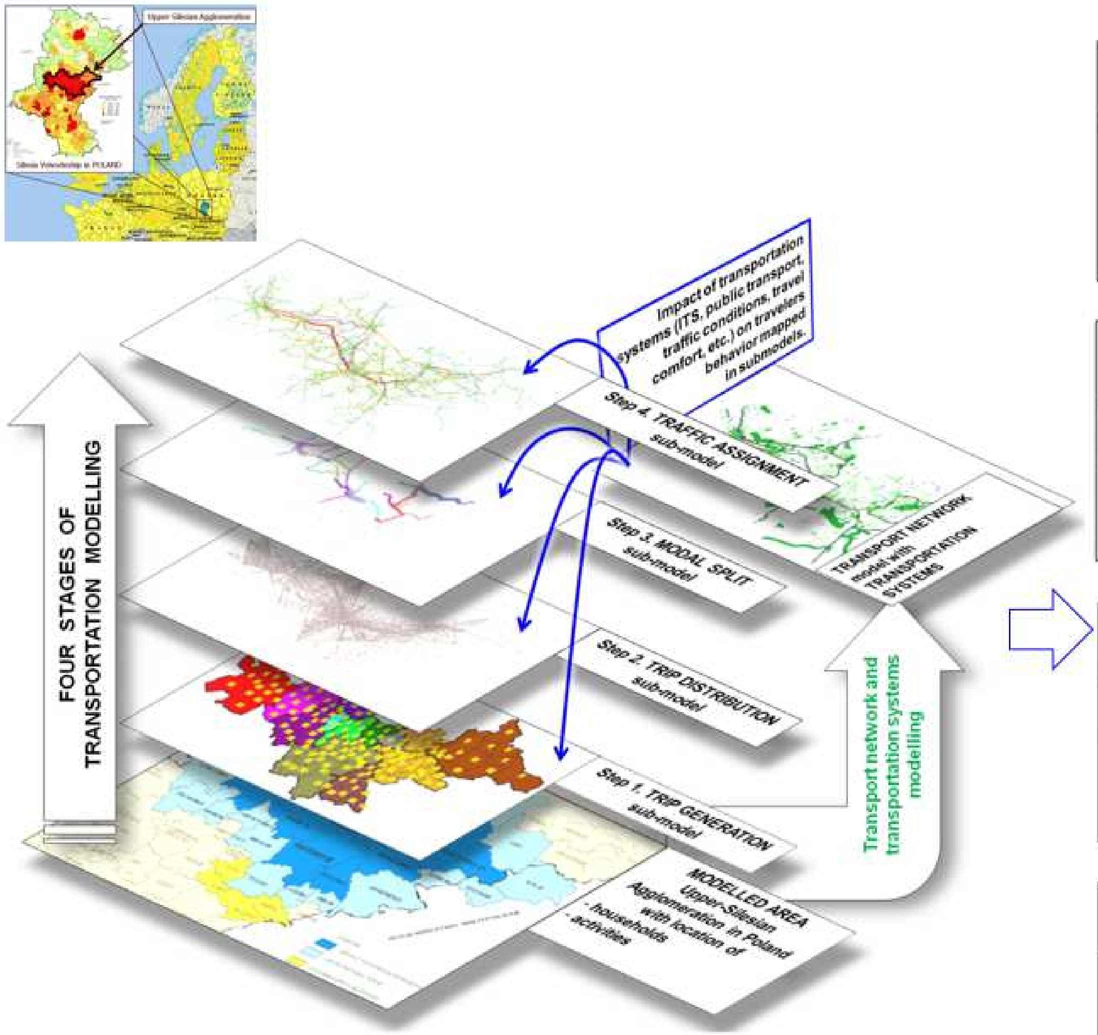
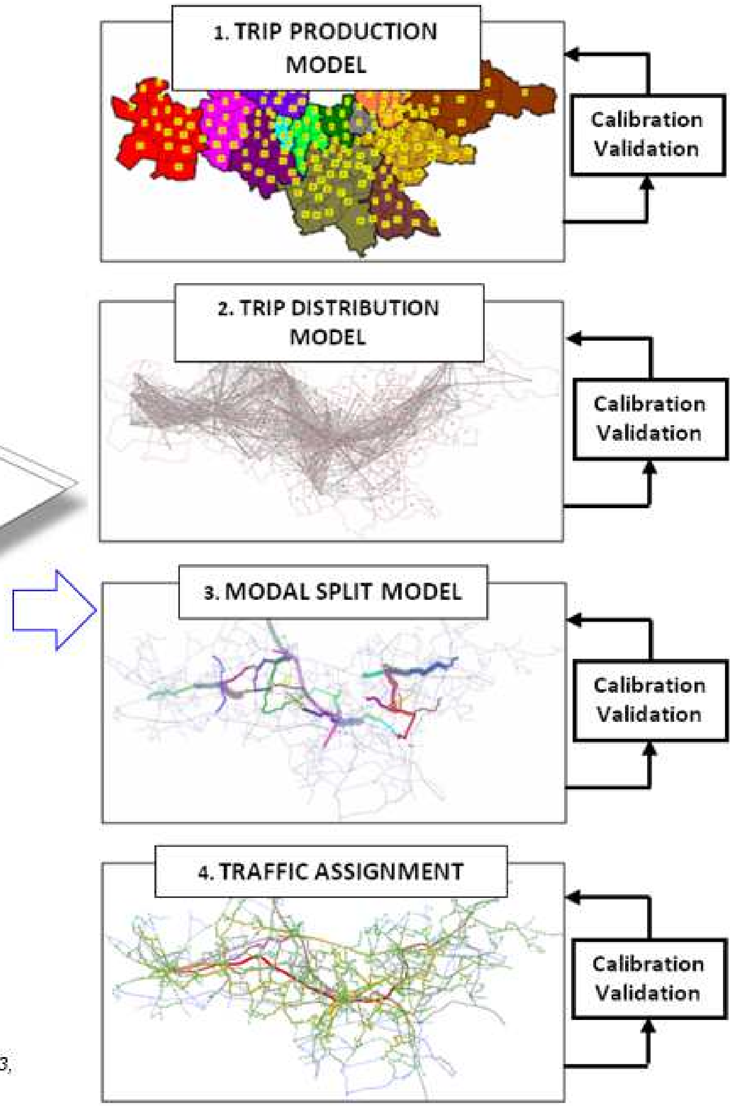
Case studies – Example of Four-Steges Transport Modeling for Upper-Silesia Urban Agglomeration in Poland





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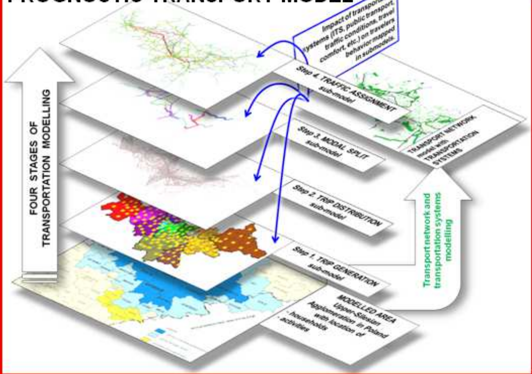
Case studies – Example of Forecasts Transport Modeling for Evaluation/Assessment of Transportation Projects for Upper-Silesia Urban Agglomeration in Poland

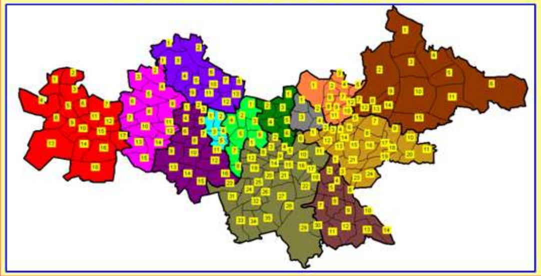
PROGNOSTIC TRANSPORT MODEL



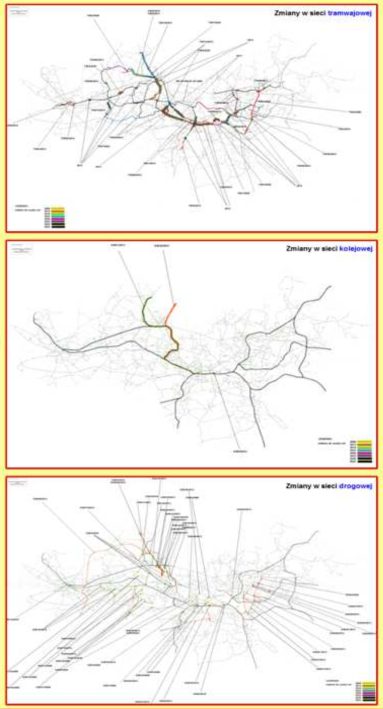
Technical Variants of Project	Example of elements of technical variants for tramway system				
	New tramway	Modernization of tramway	Modernization of tramway track	Priority on intersections	Passenger Information System
V0	N	N	N	N	N
V1	N	N	Y	N	N
V2	N	N	Y	Y	Y
V3	Y	Y	Y	Y	Y
V4	Y	N	Y	Y	Y

	Base year	Horizons of Forecasts					
Technical Variants of Project	2010	2015	2020	2025	2030	2035	2040
1	2	3	4	5	6	7	8
V0	W0_2010	W0_2015	W0_2020	W0_2025	W0_2030	W0_2035	W0_2040
V1	x	W1_2015	W1_2020	W1_2025	W1_2030	W1_2035	W1_2040
V2	x	W2_2015	W2_2020	W2_2025	W2_2030	W2_2035	W2_2040
V3	x	W3_2015	W3_2020	W3_2025	W3_2030	W3_2035	W3_2040
V4	x	W4_2015	W4_2020	W4_2025	W4_2030	W4_2035	W4_2040

CHANGES IN TRAVEL DEMAND



CHANGES IN TRANSPORT SYSTEMS



Source: based on ***Karoń G.: Travel Demand and Transportation Supply Modeling for Agglomeration without Transportation Model.***
In J. Mikulski (Ed.): Activities of Transport Telematics, CCIS 395, pp. 284-293, Springer-Verlag Berlin Heidelberg 2013.

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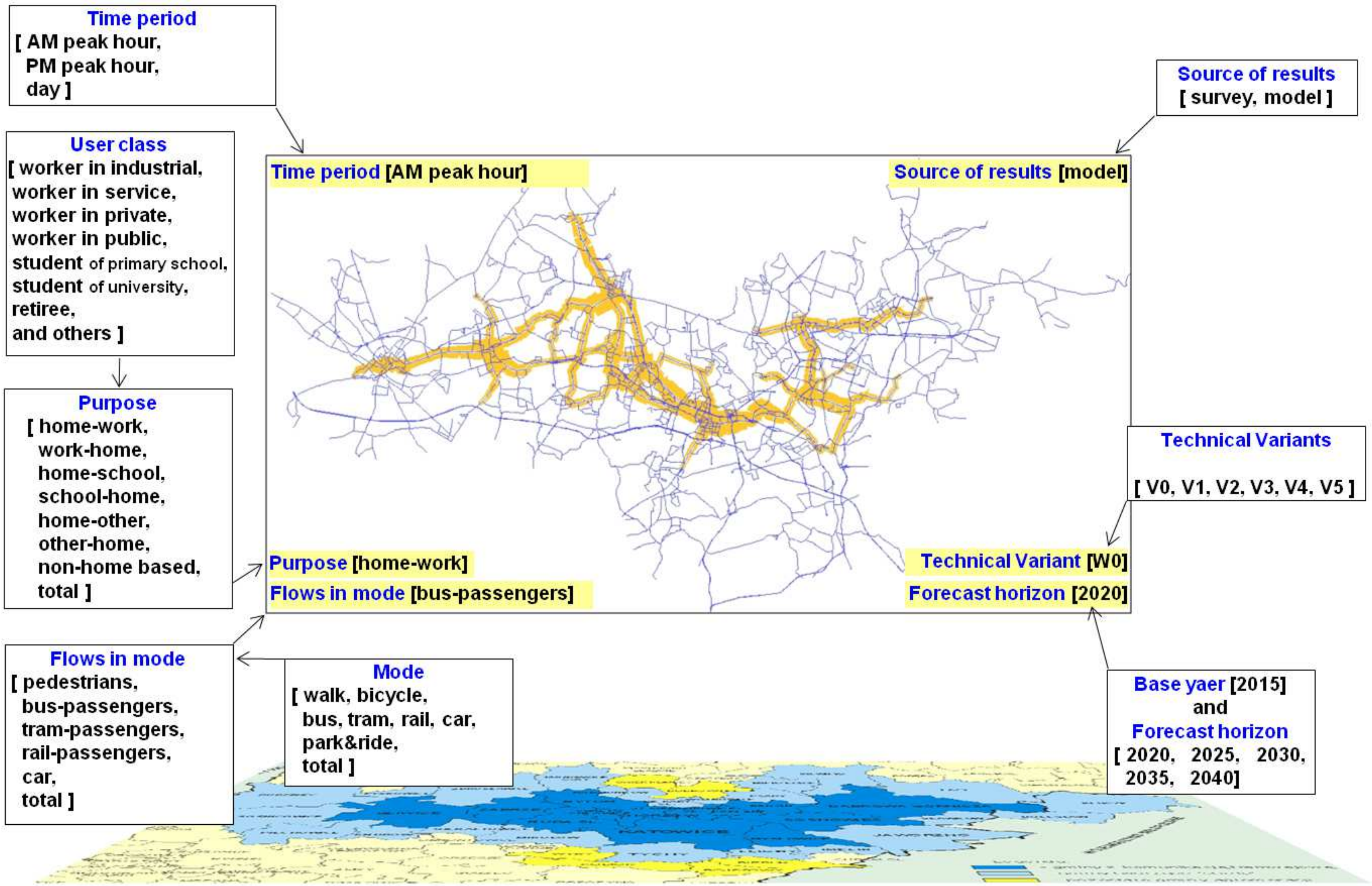
Case studies – Example of Results of Transport Modelling (Traffic Flows Assignment in Transport Network) for Transportation Projects in Upper-Silesia Urban Agglomeration in Poland



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Results and Discussion

- ✓ **The presented main algorithm is the concept and the basis for further work on detailed algorithms for particular key issues of transport analyzes**
- ✓ **The main algorithm was created and verified during many transport projects implemented in Poland**
- ✓ **Detailed algorithms related to key issues are currently in the generalization phase, and because there is a large variation in the methods of solving key issues, the creation of these algorithms are iterative processes**

Conclusions

- ➢ **The development of the concept of the main algorithm required the identification of key determinants related to Urban Area and Transportation Systems, which will change as a result of changes in IT technologies, especially in connection with the Internet of Things**
- ➢ **The complexity of transport problems, transport services and methods of designing and optimizing these issues requires the use of systems engineering methods for a systemic and holistic approach in the algorithmization process**

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Thank you for your attention

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