

DEVELOPMENT OF AN USER-FRIENDLY INTERFACE USING GAMS AND GAMS MIRO.

Final presentation | Advanced Data & Business Analytics

USER-FRIENDLY INTERFACE FOR MATHEMATICAL MODELS USING GAMS AND GAMS MIRO.

01

What was the project's goal and what was the motivation behind it?

Motivation & project framework

03

What does the final dashboard look like and what steps did we take to get there?

Implementation & Dashboard

05

What lessons have we learned and where is there still a need for future optimization?

Conclusion and outlook

02

How is the optimization model for the network design problem build?

04

What hurdles did we face during implementation?

Motivation & project framework

„What was the project's goal and what was the motivation behind it?“



VISUALIZATION OF OPTIMIZATION MODELS: UNLOCKING NUMEROUS BENEFITS AND ENHANCED INSIGHTS.

"Develop an user-friendly interface for a given mathematical optimization model."

Optimization Model



Solver code



Adding **visualization** and **interactive components** to an optimization model **enables several advantages ...**

✓ Enhanced Understanding

✓ Better interpretability

Visualization

New



Interactive

New

✓ Efficient

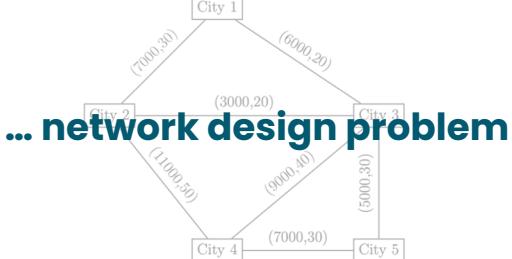
✓ Improved learning

✓ Interactive Analysis

✓ More fun 😊

✓ Increased Accessibility

The following were provided ...



... poor and incomplete code

```
variable  
if the connection i to j is built 0 otherwise;  
variable  
of the objective function;  
variable  
number of passengers starting their trip in u;  
objective function  
function  
flow;  
$(ord(u)<ord(v))..sum((i)$(E(i,v)),X(u,i,v))-sum((j)$(E(v,j)),X(u,v,j))  
coupling;  
(u,i,j)$(E(i,j) and ord(i)< ord(j)).X(u,i,j)+x(u,j,i)=l=d(u,u)*y(i,j);  
budget;  
sum((i,j)$(E(i,j) and ord(i)< ord(j)),c(i,j)*y(i,j))=l=B;
```



... missing **visualizations** and **interactive components**

GAMS AND GAMS MIRO COMBINE THE FUNCTIONS OF OPTIMIZATION AND VISUALIZATION SOFTWARE INTO A SINGLE TOOL.

Optimization & modeling software

- **Creation and optimization** of real-world problems in a software environment.
- Uses **optimization algorithms** such as LP, MILP, NLP to find the best values for decision variables.
- It is applied in **many industry areas**.

Visualization software

- Enables the **representation of data in graphical form**, such as charts, graphs, and interactive dashboards.
- Aids in **identifying patterns, trends, and anomalies** in large datasets.



- ✓ Both tools within a **single software**.
- ✓ **Popularity in the industry** is steadily increasing.



mosek



Different software for ...

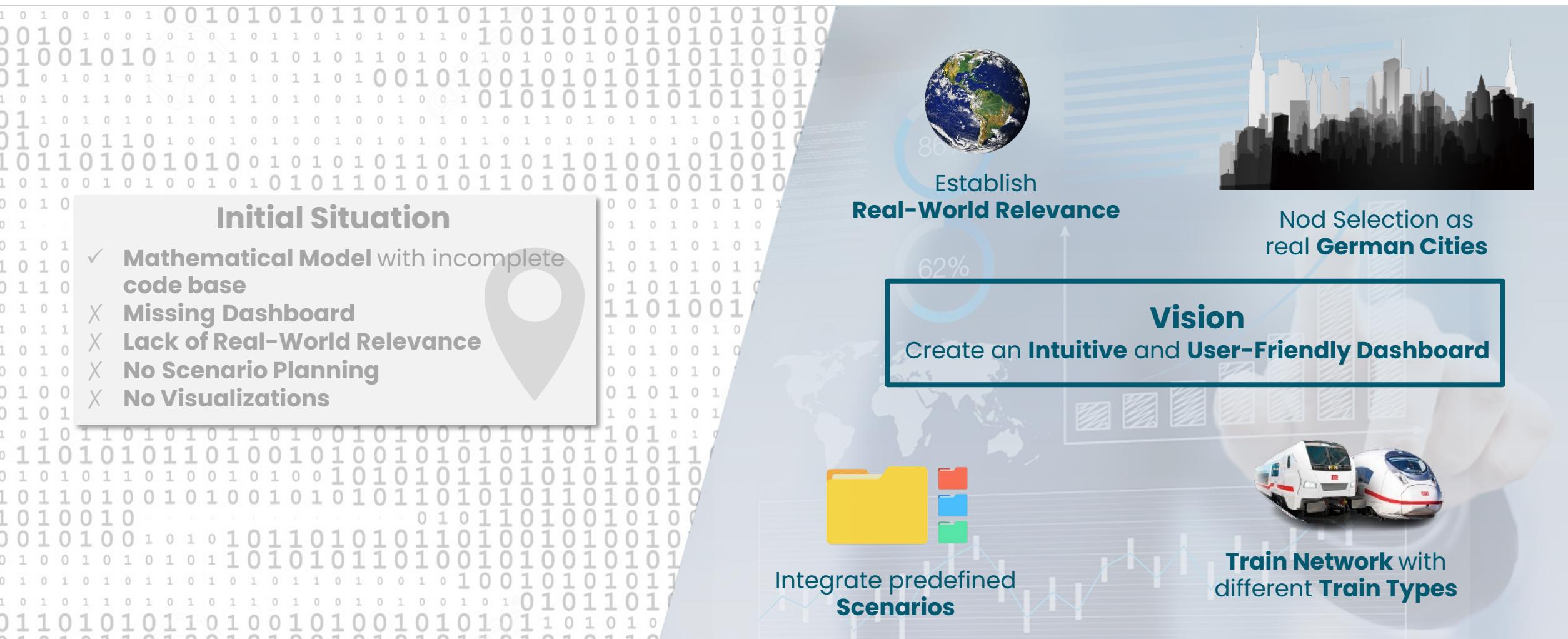
... different applications.



QlikView



FROM INITIAL STATE TO VISION: SETTING OUR TARGET OBJECTIVES AND GENERATION OF A TARGET IMAGE.



Introduction of the the network design problem

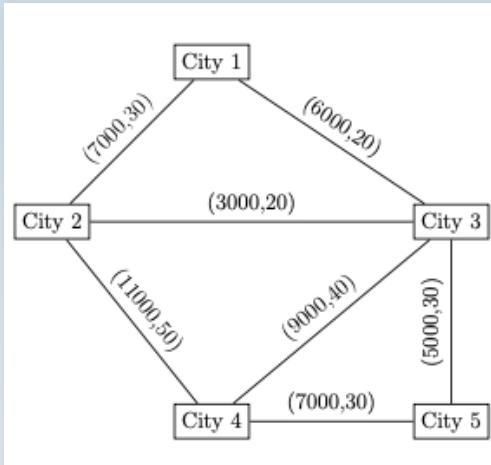
„What is the network design problem and how is the optimization model built?”



```
header());?>
$logo_pos = $menu_pos;
if (isset($theme_options['menu_pos'])) {
    $menu_pos = esc_attr($theme_options['menu_pos']);
}
$logo_pos_class = $menu_pos_class = '';
if ($menu_pos == $logo_pos) {
    $menu_pos_class = 'menu-logo';
}
```

THE NETWORK DESIGN PROBLEM AIMS TO MINIMIZE PASSENGER TRAVEL TIME WHILE ADHERING TO OPERATIONAL RESTRICTIONS.

Initial Network



Input

V: cities

E: connections

c_{ij}: construction costs

B: budget

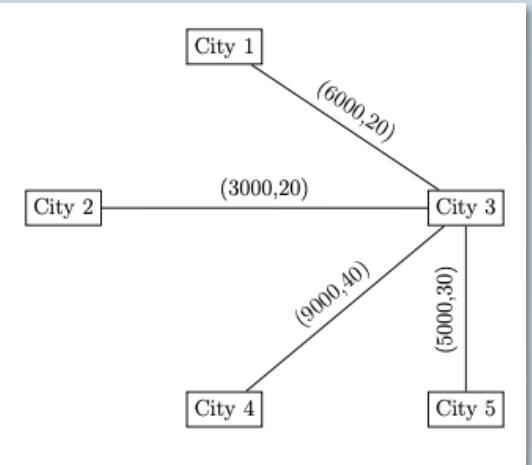
t_{ij}: travel time

d_{uv}: expected number of passengers

Mathematical Model

$$\begin{aligned}
 & \text{Minimize } G = \sum_{i,j \in E} t_{ij} \sum_{u \in V} x_{uuj} \\
 & \sum_{(i,v) \in E} x_{uiv} - \sum_{(v,j) \in E} x_{uvj} = d_{uu} \quad \forall i, v \in V | u \neq v \\
 & x_{uuj} + x_{uji} \leq d_{uu} \times y_{ij} \quad \forall u \in V, (i,j) \in E \\
 & \sum_{(i,j) \in E | i < j} c_{ij} \times y_{ij} \leq B \quad \forall u \in V, (i,j) \in E | i < j \\
 & x_{uuj} \geq 0 \quad \forall u \in V, (i,j) \in E \\
 & y_{ij} \in \{0,1\} \quad \forall (i,j) \in E | i < j
 \end{aligned}$$

Optimal Solution



Output

y_{ij}: 1, if edge is built (0, otherwise)

x_{uuj}: number of passengers starting trip in u and traveling from i to j



Objective Function

- Minimize total travel time



Constraints

A FUNDAMENTAL UNDERSTANDING OF THE OPTIMIZATION MODEL IS KEY TO INTERACTIVE APPLICATIONS.

Sets

V: sorted nodes (indices: i, j, u, v)

E: edges; with edge $[i, j] \in E$, where $i < j$

Variables

y_{ij} : 1, if edge $[i, j]$ is built (0, otherwise) sorted nodes (indices: i, j, u, v) if edge

x_{uuj} : number of passengers starting their trip in node u and traveling from i to j

$$\text{Minimize } G = \sum_{i,j \in E} t_{ij} \sum_{u \in V} x_{uuj}$$

$$\sum_{(i,v) \in E} x_{uiv} - \sum_{(v,j) \in E} x_{uvj} = d_{uu} \quad \forall i, v \in V | u \neq v$$

$$x_{uuj} + x_{uji} \leq d_{uu} \times y_{ij} \quad \forall u \in V, (i, j) \in E$$

$$\sum_{(i,j) \in E | i < j} c_{ij} \times y_{ij} \leq B \quad \forall u \in V, (i, j) \in E | i < j$$

$$x_{uuj} \geq 0 \quad \forall u \in V, (i, j) \in E$$

$$y_{ij} \in \{0,1\} \quad \forall (i, j) \in E | i < j$$

A FUNDAMENTAL UNDERSTANDING OF THE OPTIMIZATION MODEL IS KEY TO INTERACTIVE APPLICATIONS.

Sets

V: sorted nodes (indices: i, j, u, v)

E: edges; with edge $[i, j] \in E$, where $i < j$

Variables

y_{ij} : 1, if edge $[i, j]$ is built (0, otherwise) sorted nodes (indices: i, j, u, v) if edge

$x_{u(i)}$: number of passengers starting their trip in node u and traveling from i to j

$$\text{Minimize } G = \sum_{i,j \in E} t_{ij} \sum_{u \in V} x_{u(i)}$$

Travel time between nodes

$$\sum_{v \in V} x_{u(v)} - \sum_{j \in V} x_{u(v)j} = d_{uu} \quad \forall i, v \in V | u \neq v$$

Minimizes the total travel time for all passengers

$$x_{u(i)} + x_{u(j)} \leq d_{uu} \times y_{ij} \quad \forall u \in V, (i, j) \in E$$

$$\sum_{(i,j) \in E | i < j} c_{ij} \times y_{ij} \leq B \quad \forall u \in V, (i, j) \in E | i < j$$

$$x_{u(i)} \geq 0 \quad \forall u \in V, (i, j) \in E$$

$$y_{ij} \in \{0,1\} \quad \forall (i, j) \in E | i < j$$

A FUNDAMENTAL UNDERSTANDING OF THE OPTIMIZATION MODEL IS KEY TO INTERACTIVE APPLICATIONS.

Sets

V: sorted nodes (indices: i, j, u, v)

E: edges; with edge $[i, j] \in E$, where $i < j$

Variables

y_{ij} : 1, if edge $[i, j]$ is built (0, otherwise) sorted nodes (indices: i, j, u, v) if edge

x_{uiv} : number of passengers starting their trip in node u and traveling from i to j

$$\text{Minimize } G = \sum_{i,j \in E} t_{ij} \sum_{u \in V} x_{uiv} \quad \text{expected number of passengers traveling}$$

from node u to node v , with $v \neq u$

$$\sum_{(i,v) \in E} x_{uiv} - \sum_{(v,j) \in E} x_{uvj} = d_{uu} \quad \forall i, v \in V | u \neq v$$

$$x_{uiv} + x_{uji} \leq d_{uu} \times y_{ij} \quad \forall u \in V, (i, j) \in E$$

► **Flow balance constraint:** ensures the number of passengers leaving a node equals the number arriving, accounting for the expected demand

$$x_{uiv} \geq 0 \quad \forall u \in V, (i, j) \in E$$
$$y_{ij} \in \{0,1\} \quad \forall (i, j) \in E | i < j$$

A FUNDAMENTAL UNDERSTANDING OF THE OPTIMIZATION MODEL IS KEY TO INTERACTIVE APPLICATIONS.

Sets

V: sorted nodes (indices: i, j, u, v)

E: edges; with edge $[i, j] \in E$, where $i < j$

Variables

y_{ij} : 1, if edge $[i, j]$ is built (0, otherwise) sorted nodes (indices: i, j, u, v) if edge

x_{uji} : number of passengers starting their trip in node u and traveling from i to j

$$\text{Minimize } G = \sum_{i,j \in E} t_{ij} \sum_{u \in V} x_{uji}$$

$$\sum_{(i,v) \in E} x_{uiv} - \sum_{(v,j) \in E} x_{uvj} = d_{vu} \quad \forall u \in V, v \in V$$
$$x_{uji} + x_{uji} \leq d_{uu} \times y_{ij} \quad \forall u \in V, (i, j) \in E$$

► **Passenger flow constraint:** ensures passenger flow on an edge does not exceed the demand if the edge is built

$$x_{uji} \geq 0$$
$$y_{ij} \in \{0,1\}$$

$$\forall u \in V, (i, j) \in E$$
$$\forall (i, j) \in E \mid i < j$$

A FUNDAMENTAL UNDERSTANDING OF THE OPTIMIZATION MODEL IS KEY TO INTERACTIVE APPLICATIONS.

Sets

V: sorted nodes (indices: i, j, u, v)

E: edges; with edge $[i, j] \in E$, where $i < j$

Variables

y_{ij} : 1, if edge $[i, j]$ is built (0, otherwise) sorted nodes (indices: i, j, u, v) if edge

$x_{u(i)}$: number of passengers starting their trip in node u and traveling from i to j

$$\text{Minimize } G = \sum_{i,j \in E} t_{ij} \sum_{u \in V} x_{u(i)}$$

$$\sum_{(i,v) \in E} x_{u(i)v} - \sum_{(v,j) \in E} x_{uvj} = d_{uu} \quad \forall i, v \in V | u \neq v$$

$$x_{u(i)} + x_{u(j)} \leq d_{uu} \times y_{ij} \quad \forall u \in V, (i, j) \in E$$

$$\sum_{(i,j) \in E | i < j} c_{ij} \times y_{ij} \leq B \quad \forall u \in V, (i, j) \in E | i < j$$

Budget constraint: ensures the total construction cost does not exceed the budget

$$y_{ij} \in \{0,1\}$$

$$\forall (i, j) \in E | i < j$$

A FUNDAMENTAL UNDERSTANDING OF THE OPTIMIZATION MODEL IS KEY TO INTERACTIVE APPLICATIONS.

Sets

V: sorted nodes (indices: i, j, u, v)

E: edges; with edge $[i, j] \in E$, where $i < j$

Variables

y_{ij} : 1, if edge $[i, j]$ is built (0, otherwise) sorted nodes (indices: i, j, u, v) if edge

$x_{u(i)}$: number of passengers starting their trip in node u and traveling from i to j

$$\text{Minimize } G = \sum_{i,j \in E} t_{ij} \sum_{u \in V} x_{u(i)}$$

$$\sum_{(i,v) \in E} x_{u(i)v} - \sum_{(v,j) \in E} x_{uvj} = d_{uu} \quad \forall i, v \in V | u \neq v$$

$$x_{u(i)} + x_{u(j)} \leq d_{uu} \times y_{ij} \quad \forall u \in V, (i, j) \in E$$

$$\sum_{(i,j) \in E | i < j} c_{ij} \times y_{ij} \leq B \quad \forall u \in V, (i, j) \in E | i < j$$

$$x_{u(i)} \geq 0 \quad \forall u \in V, (i, j) \in E$$

► **Non-negativity constraint:** ensures the number of passengers on any edge is non-negative

A FUNDAMENTAL UNDERSTANDING OF THE OPTIMIZATION MODEL IS KEY TO INTERACTIVE APPLICATIONS.

Sets

V: sorted nodes (indices: i, j, u, v)

E: edges; with edge $[i, j] \in E$, where $i < j$

Variables

y_{ij} : 1, if edge $[i, j]$ is built (0, otherwise) sorted nodes (indices: i, j, u, v) if edge

$x_{u(i)}$: number of passengers starting their trip in node u and traveling from i to j

$$\text{Minimize } G = \sum_{i,j \in E} t_{ij} \sum_{u \in V} x_{u(i)}$$

$$\sum_{(i,v) \in E} x_{u(i)v} - \sum_{(v,j) \in E} x_{uvj} = d_{uu} \quad \forall i, v \in V | u \neq v$$

$$x_{u(i)} + x_{u(j)} \leq d_{uu} \times y_{ij} \quad \forall u \in V, (i, j) \in E$$

$$\sum_{(i,j) \in E | i < j} c_{ij} \times y_{ij} \leq B \quad \forall u \in V, (i, j) \in E | i < j$$

$$x_{u(i)} \geq 0 \quad \forall u \in V, (i, j) \in E$$

$$y_{ij} \in \{0,1\} \quad \forall (i, j) \in E | i < j$$

► **Binary constraint:** ensures that an edge is either built (1) or not built (0)

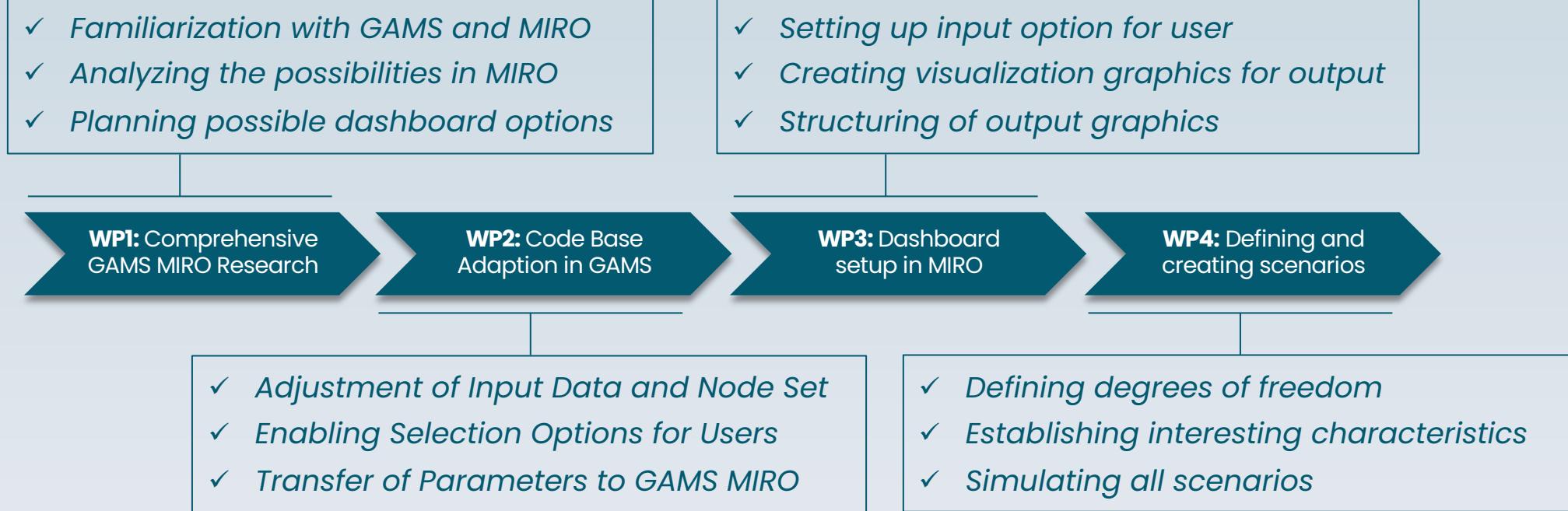
Implementation & Dashboard

„What does the final dashboard look like and what steps did we take to get there?“

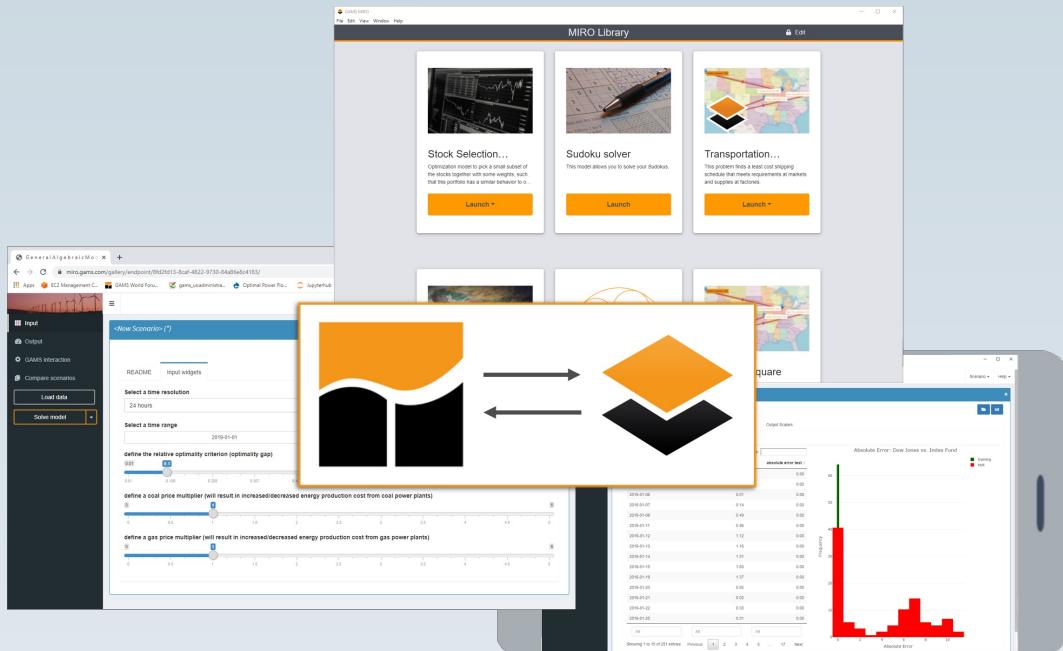


```
if (isset($theme_options['header'])) {  
    $logo_pos = $menu_pos = $theme_options['header'];  
    if (isset($theme_options['header'])) {  
        $logo_pos = esc_attr($theme_options['header']);  
        $menu_pos = esc_attr($theme_options['header']);  
    } else {  
        $logo_pos = esc_attr($theme_options['header']);  
        $menu_pos = esc_attr($theme_options['header']);  
    }  
}  
  
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        $menu_pos = esc_attr($theme_options['header']);  
    }  
}
```

USER-FRIENDLY INTERFACE FOR MATHEMATICAL MODELS USING GAMS AND GAMS MIRO.



THE GAMS MIRO DOCUMENTATION IS A HELPFUL SUPPORT AND DEMONSTRATES THE DIVERSE POSSIBILITIES OF THE TOOL.



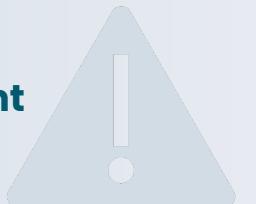
- **Read the documentation** of GAMS and GAMS Miro and **familiarized with the functions**.
- Went through the **provided example dashboards**.
- Analyzed **further implementation steps**.



- GAMS MIRO offers a **variety of customization options** and the ability to build **an interactive dashboard** according to our requirements



- The provided GAMS code **needs significant adjustments**.



THE FOUNDATION OF THE CODE MUST BE ADJUSTED TO CREATE REALISM AND ENABLE THE INTERACTIVITY OF THE DASHBOARD.

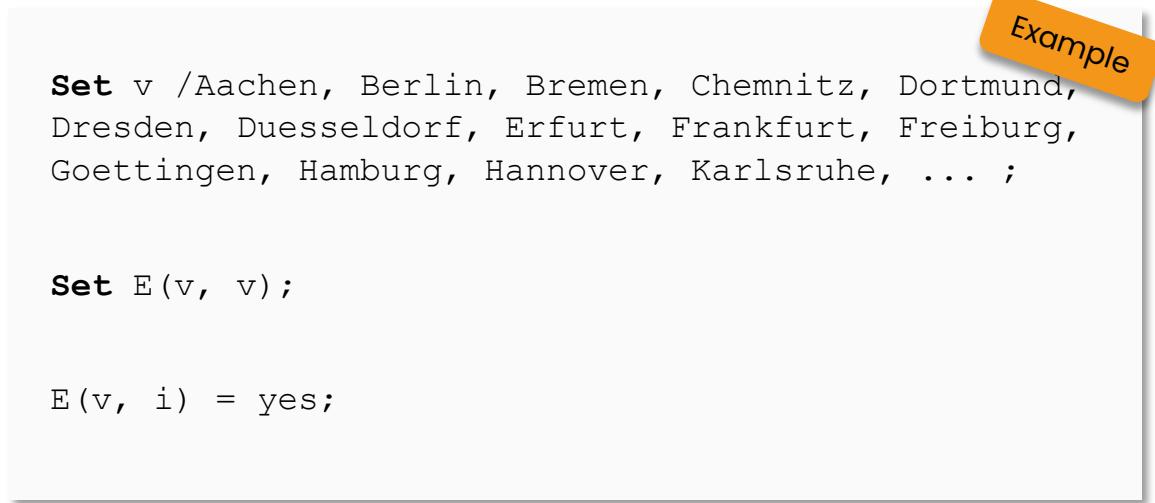
Defining the nodes to be simulated through real city selection

Set v /Aachen, Berlin, Bremen, Chemnitz, Dortmund,
Dresden, Duesseldorf, Erfurt, Frankfurt, Freiburg,
Goettingen, Hamburg, Hannover, Karlsruhe, ... ;

Set E(v, v);

E(v, i) = yes;

Example



- **Expand the number of nodes** to be optimized.
- Include up to **largest cities** in the **16 federal states**.
- Use real **geographic coordinates**.

Adjust the input data and establish a connection to reality



Real World Assumption



Gravity_Model.gms

- Adjust construction costs [$c(v,v)$] and travel times [$t(v,v)$] using **more realistic values** through appropriate assumptions and simplifications.
 - **Example:** City distance * train speed = travel time.
- Modeling traffic between cities by previously **incorporating a gravity model**.

THE FOUNDATION OF THE CODE MUST BE ADJUSTED TO CREATE REALISM AND ENABLE THE INTERACTIVITY OF THE DASHBOARD.

Enable input selection by the user

```
If (Subcityselction('East'),
    v_subset('Berlin') = yes;
    v_subset('Potsdam') = yes;
    v_subset('Magdeburg') = yes;
    v_subset('Leipzig') = yes;
    v_subset('Erfurt') = yes;
);
```

Example

- Making the GAMS **code more flexible**.
- Enable external input through **dynamic quantities** and **adjustable parameters**.

Linking with a GDX file for data transfer

```
$GDXIN data_general.gdx
$LOAD long, lat, ...
$GDXIN
```



Example

- Input data is **transferred via a GDX file** and not embedded in the code itself.
- Enables **larger datasets** and more **flexible adjustments** during the coding phase.

Linking GAMS MIRO and GAMS for mutual data exchange

\$OnExternalInput

Parameter B /1000/;

\$OffExternalInput

\$OnExternalOutput

Table map(v, i, mapHdr);

Parameter totalcost;

\$OffExternalOutput

Example

- Creating **transparent code blocks**.
- Ensuring **data exchange for input and output data**.

UNLOCK FULL POTENTIAL FOR THE END USER WITH INTUITIVE INPUT AND OUTPUT VISUALIZATIONS.

Initial Situation Input

Global Info	Budget	Number of Passengers	Fixed Costs	Travel Time
-------------	--------	----------------------	-------------	-------------

Final Situation Input

Global Information	User Input		
	Budget	Train Type	Region

UNLOCK FULL POTENTIAL FOR THE END USER WITH INTUITIVE INPUT AND OUTPUT VISUALIZATIONS.

Initial Situation^{Input}

Old

Global Info	Budget	Number of Passengers	Fixed Costs	Travel Time
-------------	--------	----------------------	-------------	-------------

Final Situation^{Input}

Revised

Global Information	Budget	User Input
	Train Type	Region

Network Design Problem.

Introduction to the problem & the interactive dashboard.

What is the network design problem doing?

The Network Planning Optimization Model is designed to **optimize the transportation network by minimizing the cumulated travel time of all passengers**, while ensuring efficient connectivity and passenger flow across cities. This model employs several parameters and variables to achieve its objectives.

All possible connections

Optimal solution
(taking in account all constraints)

HOW does the model work?

The optimization model will compute the **minimum total travel time for all passengers**, adhering to all relevant constraints. The output will include the **decision variables x_{ij} and y_i** .

Input

Sets:
V: cities
E: connections between cities

Parameters:
B: Budget
t_i: travel time ...
c_{i,j}: construction costs ...
d_i: expected number of passengers ...
...for each connection

Optimization Model

Objective: minimizing total travel time of all passengers

Constraints: ensuring functionality of the model

$$\begin{aligned} \text{Minimize } & \sum_{i \in V} \sum_{j \in V} a_{ij} \\ \text{Subject to } & \sum_{j \in V} a_{ij} = \sum_{i \in V} a_{ij} = 1 \quad \forall i \in V \\ & \sum_{j \in V} a_{ij} \leq d_i \quad \forall i \in V \\ & c_{ij} \cdot a_{ij} \leq B \quad \forall i, j \in V \\ & t_{ij} \cdot a_{ij} \leq T \quad \forall i, j \in V \\ & a_{ij} \geq 0 \quad \forall i, j \in V \end{aligned}$$

Output

Objective Value
G: total travel time of all passengers

Variables
 y_i : 1 if city i is a hub and 0 otherwise
 x_{ij} : number of passengers starting their trip in city i and travelling from city i to j

WHERE is the model connected to reality?

The model is based on a railway network in Germany; it integrates real geodata and simplified assumptions derived from real-world conditions.

Multiple regions
Selection of a north, east, south, west region in Germany

Different Train Types
Selection between an ICE and an RE train

Integration of Gravity Model
Simulation of the traveling people between cities by an demand model

Real life Assumptions
Adjusting the input data via real world assumptions

Train Speed
ICE: 250 km / h
RE: 125 km / h

Construction cost
ICE: 500 mio € + 10 mio. €/km
RE: 250 mio € + 15 mio. €/km

You want to learn more about the gravity model? Click on the link below to see the full model in GitHub.

[View GitHub](#)

HOW do I use the dashboard?

The user-friendly GAMS interface allows users to select relevant input options and analyze them in the output section using an intuitive dashboard and visualizations. The setup also enables the comparison of predetermined scenarios.

1. Select Input

The user has the flexibility to customize the input options across various aspects, such as:

- Regional Selection
- Budget
- Train Type

2. Interpretate Outlook

The user can easily review the output through a Management Summary, which displays all essential information at a glance.

1047239
Out travel time (h) (travel time)
1357632
Total cost (mio €)
16.92
Budget (mio €)
16.92
Budget of revenue (mio €)

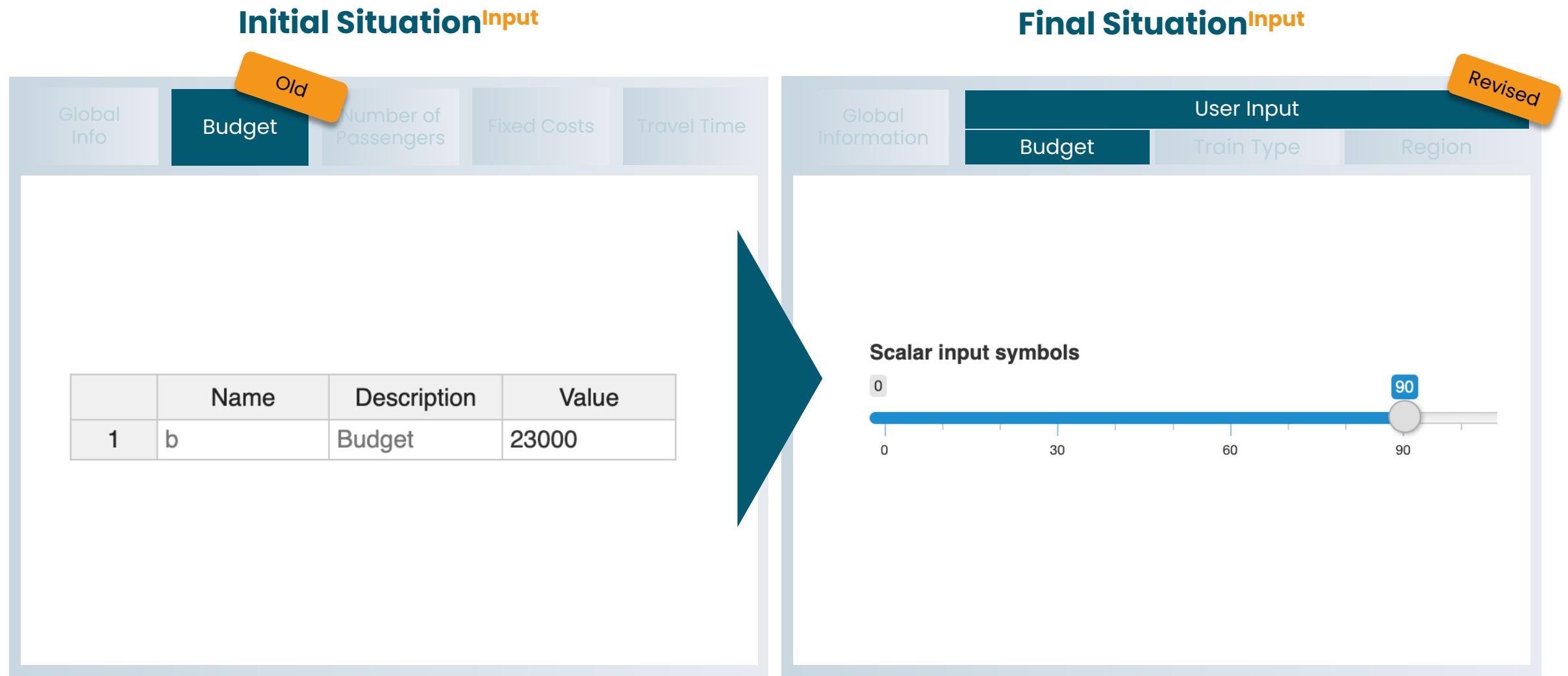
3. Compare Scenarios

The user can compare 30 distinct scenarios to enhance their understanding of the outputs and facilitate more informed decision-making.

You want to get the full GAMS code? Click on the link below to see the full model in GitHub.

[View GitHub](#)

UNLOCK FULL POTENTIAL FOR THE END USER WITH INTUITIVE INPUT AND OUTPUT VISUALIZATIONS.



UNLOCK FULL POTENTIAL FOR THE END USER WITH INTUITIVE INPUT AND OUTPUT VISUALIZATIONS.

Initial Situation^{Input}

	Global Info	Budget	Number of Passengers	Fixed Costs	Travel Time
			Removed	Removed	Removed

Number of Passengers travelling from city u to v

	city u	city 1	city 2	city 3	city 4	city 5
1	city1	900.00	250.00	400.00	100.00	150.00
2	city2	250.00	1400.00	500.00	250.00	400.00
3	city3	400.00	500.00	1300.00	300.00	100.00

Fixed Costs

	city u	city v	fixed cost
1	city1	city2	7000.00
2	city1	city3	6000.00
3	city2	city1	7000.00

Travel Time

	trip i	trip j	value of travel time for the direct trip from i to j
1	city1	city2	30.00
2	city1	city3	20.00
3	city2	city1	30.00
4	city2	city3	20.00



```
$gdxIn data.gdx
$load long, lat, inhabitants t_subset, c_subset, d_subset
$GDXIN
```

UNLOCK FULL POTENTIAL FOR THE END USER WITH INTUITIVE INPUT AND OUTPUT VISUALIZATIONS.



Final Situation **Input**

New

Global Information

User Input

Budget Train Type Region

Regional Selection

Region i

Metropolises

Metropolises

North

East

South

West

Train Type

Train Type i

ICE

ICE RE

This screenshot shows a user interface for selecting regional and train type parameters. At the top, there's a header with 'Global Information' and three tabs: 'User Input' (selected), 'Budget', 'Train Type', and 'Region'. A yellow 'New' badge is in the top right. Below, under 'Regional Selection', there's a dropdown menu for 'Region' with options like Metropolises, North, East, South, and West. Under 'Train Type', there's a dropdown menu for 'Train Type' with options like ICE and RE.

UNLOCK FULL POTENTIAL FOR THE END USER WITH INTUITIVE INPUT AND OUTPUT VISUALIZATIONS.

Initial Situation Output

Connections	Number Passengers starting trip in	Objective Value
-------------	------------------------------------	-----------------

Final Situation Output

Management Summary		Input Data (Costs, Travel time, All Passengers)	Output Data (Travelling Passengers, Connection built)
Route Map	KPIs		

UNLOCK FULL POTENTIAL FOR THE END USER WITH INTUITIVE INPUT AND OUTPUT VISUALIZATIONS.

Initial Situation Output

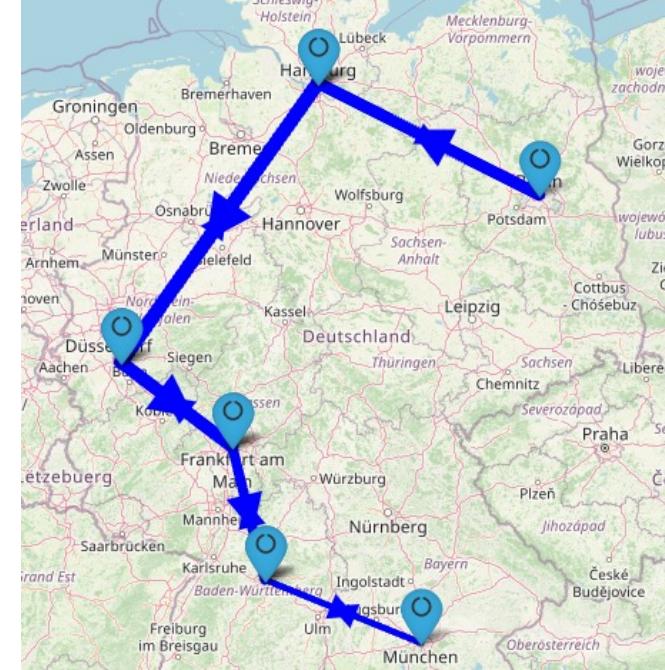
Old

Connections		Number Passengers starting trip in	Objective Value
city1	city3	Header	
		value	
		level	1.00
		lower	0.00
		marginal	0.00
		scale	1.00
		upper	1.00

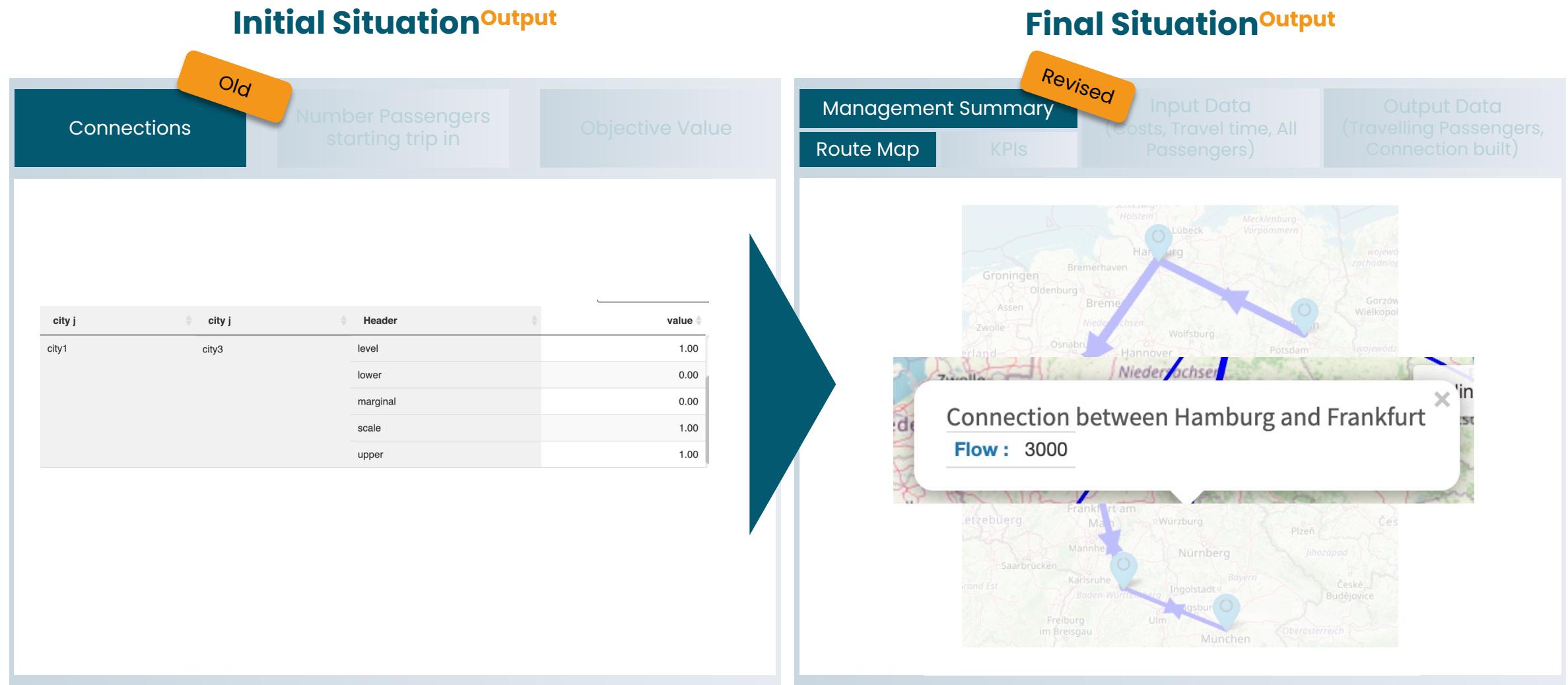


Final Situation Output

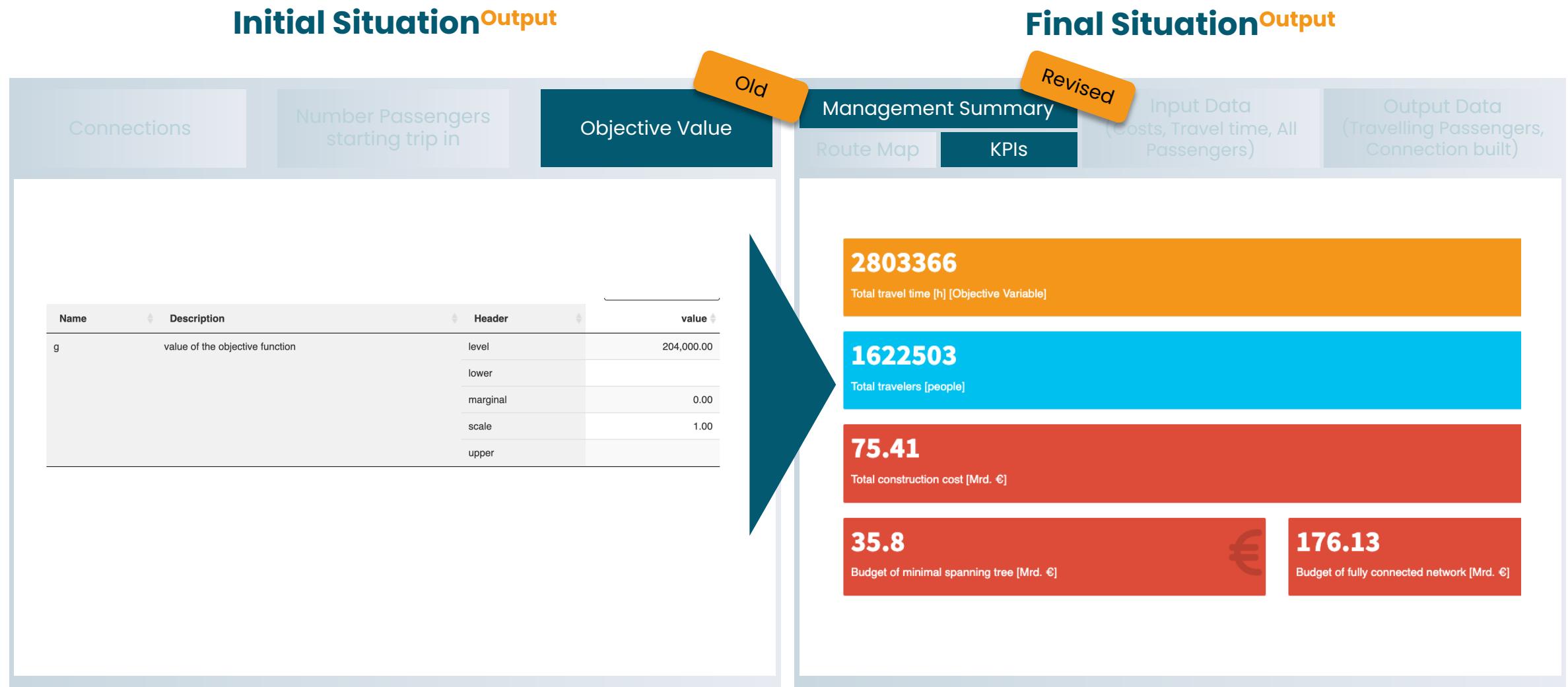
Revised

Management Summary		Input Data (Costs, Travel time, All Passengers)	Output Data (Travelling Passengers, Connection built)
Route Map	KPIs		
			

UNLOCK FULL POTENTIAL FOR THE END USER WITH INTUITIVE INPUT AND OUTPUT VISUALIZATIONS.



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Data Tables

Input Data:

Predetermined parameters including construction costs, travel time, and passenger volume for each connection

Output Data

Provides the user with an option to view detailed data of consolidated data in the management summary if desired

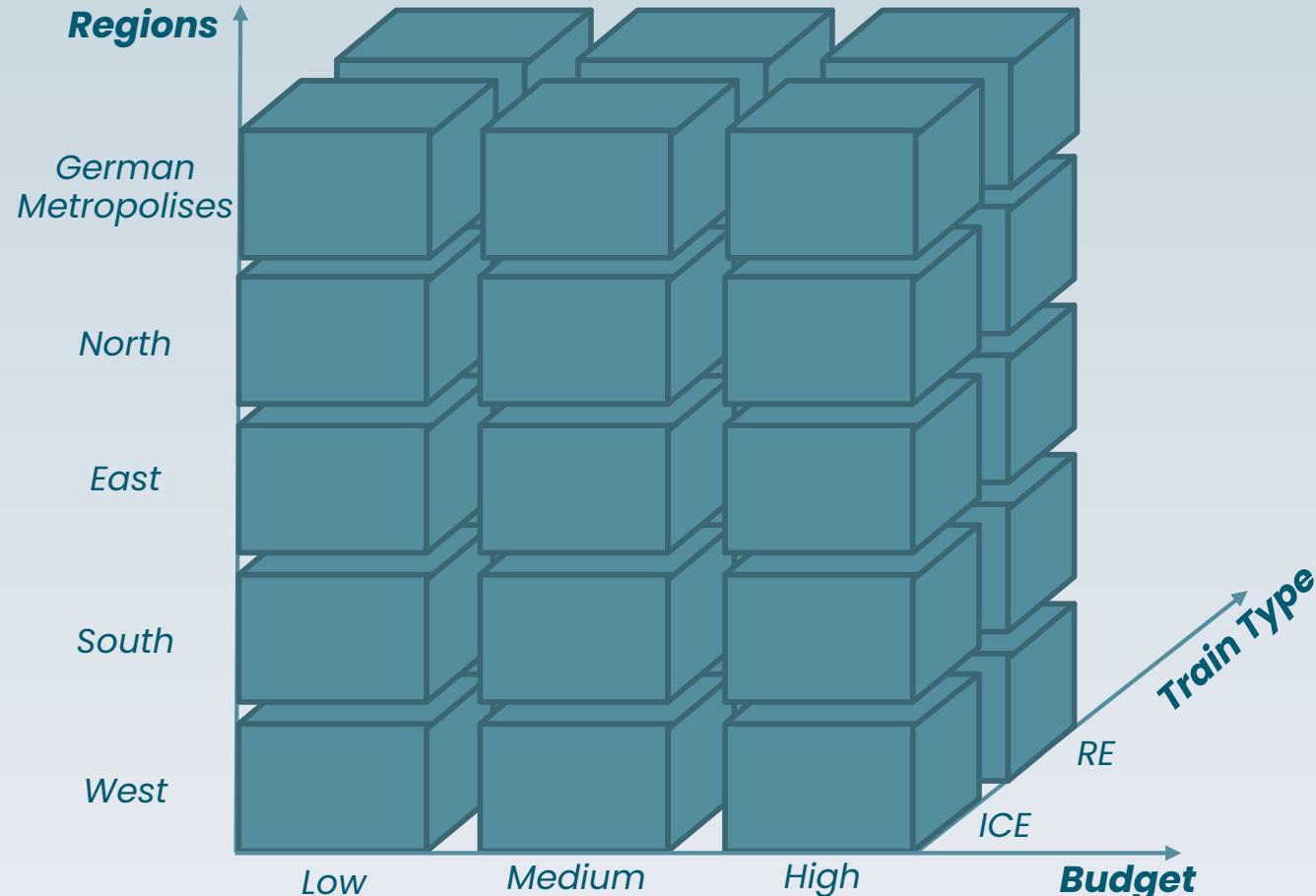
Final Situation Output

The screenshot displays a software interface for managing transportation routes. At the top, there are three tabs: 'Management Summary', 'Route Map', and 'KPIs'. Below these, two main sections are shown: 'Input Data (Costs, Travel time, All Passengers)' and 'Output Data (Travelling Passengers, Connection built)'. Each of these sections has a 'Data Table' callout pointing to its respective table. The tables are organized by city pairs (e.g., Berlin-Berlin, Berlin-Frankfurt, etc.) and show various metrics like cost, travel time, and passenger counts.

Cities	Berlin	Frankfurt	Hamburg	Koeln
Berlin	0.50	13.23	8.18	14.86
Frankfurt	1.70		1.57	0.61
Hamburg		Berlin	Frankfurt	Hamburg
Koeln				Koeln
Berlin	3,644,830.00	27,298.00	66,031.00	38,320.00
Frankfurt	119,401.00	753,056.00	62,755.00	40,529.00
Hamburg	125,109.00	27,184.00	1,841,180.00	38,728.00
Koeln	119,025.00	28,781.00	63,488.00	1,085,660.00

Cities	Cities	Passengers
Berlin	Hamburg	600,232.000
Frankfurt	Berlin	
Frankfurt	Frankfurt	
Hamburg	Hamburg	
Koeln		1
Stuttgart		1
		1

ENABLE USER-FRIENDLY SCENARIO COMPARISONS WITH REAL-WORLD CONTEXTUALIZATION.



- **30 Predefined Scenarios:** Automatically generated from three key dimensions—Regions, Budget, and Train Type.
- **Comparative Opportunities:** Allows users to easily compare scenarios to streamline decision-making.
- **User-Friendly Analysis:** Simplifies results analysis by providing ready-made scenarios, reducing user workload.

Problems & challenges

„What hurdles did we face during implementation?



ON THE WAY TO THE FINAL INTERFACE, THERE WERE CHALLENGES THAT COULD BE RESOLVED WITH THE APPROPRIATE SUPPORT.

Balance realism and simplicity

Greenfield network planning

Restrictive city selection

Costs and travel times

 **Making simplified but realistic assumptions**

Implementation difficulties in coding

Calculation Minimum Spanning Tree

Integration Gravity Model

 **Quick and effective support** from Lorena

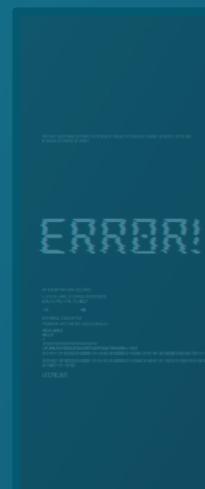


Unexpectedly high coding proportion

City expansion

Code architecture for large datasets

 **Learning GAMS MIRO and GAMS code**



Bugs due to MIRO development stage

Map display

Management summary

Live display in configuration mode

 **Quick and efficient support** from the GAMS and GAMS MIRO team

Conclusion and outlook

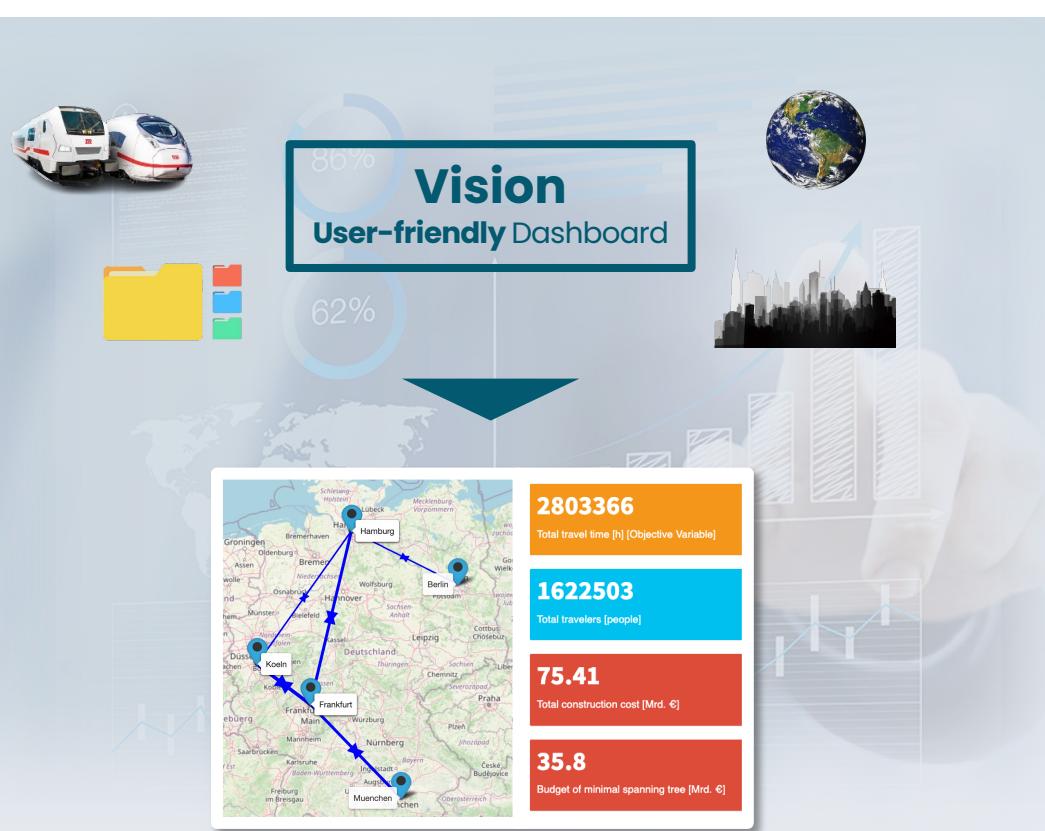
"What lessons have we learned and where is there still a need for future optimization?"



```
if (isset($theme_options['header'])) {  
    $menu_pos = $menu_pos = fruitful_get_theme_option('menu_pos');  
    if (isset($theme_options['menu_pos'])) {  
        $menu_pos = esc_attr($theme_options['menu_pos']);  
    } else {  
        $menu_pos = 'left';  
    }  
    $logo_pos = $logo_pos = fruitful_get_theme_option('logo_pos');  
    if (isset($theme_options['logo_pos'])) {  
        $logo_pos = esc_attr($theme_options['logo_pos']);  
    } else {  
        $logo_pos = 'left';  
    }  
    $menu_pos_class = fruitful_get_theme_option('menu_pos_class');  
    if (isset($theme_options['menu_pos_class'])) {  
        $menu_pos_class = esc_attr($theme_options['menu_pos_class']);  
    } else {  
        $menu_pos_class = 'menu-left';  
    }  
    $logo_pos_class = fruitful_get_theme_option('logo_pos_class');  
    if (isset($theme_options['logo_pos_class'])) {  
        $logo_pos_class = esc_attr($theme_options['logo_pos_class']);  
    } else {  
        $logo_pos_class = 'logo-left';  
    }  
}
```

PROJECT ACHIEVEMENTS AND FUTURE POTENTIALS FOR IMPROVEMENTS OF THE DEVELOPED GAMS INTERFACE.

"Develop an user-friendly interface for a given mathematical optimization model."



... but there still are potentials for further development

- Possibility to **combine ICE and RE tracks**.
- Increased **realism** by considering **building restrictions**
- Enhance efficiency and accessibility through the **integration** of **various modes of transport** such as **rail, road, and boat**
- Model application on **established Networks** to optimize and enhance the performance of **existing transportation networks**.

Thank you for your Attention are there any questions?

Feel free to contact us anytime for a live demo in **GAMS MIRO** or the **GitHub file**.



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- General settings
- Symbols
- Tables
- Input widgets
- Graphs
- Scenario analysis
- Database management

Configure input widgets

All symbols / widgets New GAMS option New double-dash parameter

Input symbol: maximum total cost allowed **Select widget type:** Slider

Choose a label: Budget

Tooltip (optional): Based on your input, the maximum budget for the optimization is set.

Minimum value: Set static minimum value: 0

Maximum value: Set static maximum value: 200

Default value: Set static default value: 35

Budget ⓘ

0 20 40 60 80 100 120 140 160 180 200

Delete **Save**

Scenario Comparison

Help

F8 F7

Assembly and Deploy

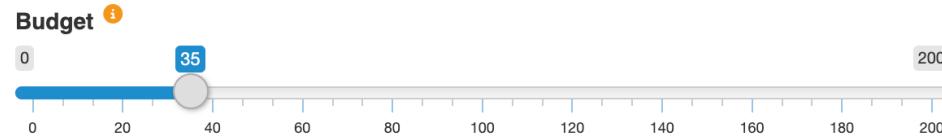
Edit README

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Lehrstuhl für Data and Business Analytics

££

5

6



7

££

Configure input widgets

All symbols / widgets New GAMS option New double-dash parameter

Input symbol: maximum total cost allowed Select widget type: Slider

Choose a label: Budget

Tooltip (optional): Based on your input, the maximum budget for the optimization is set.

Minimum value: Set static minimum value: 0

Maximum value: Set static maximum value: 200

Default value: Set static default value: 35

1

2

3

4

5

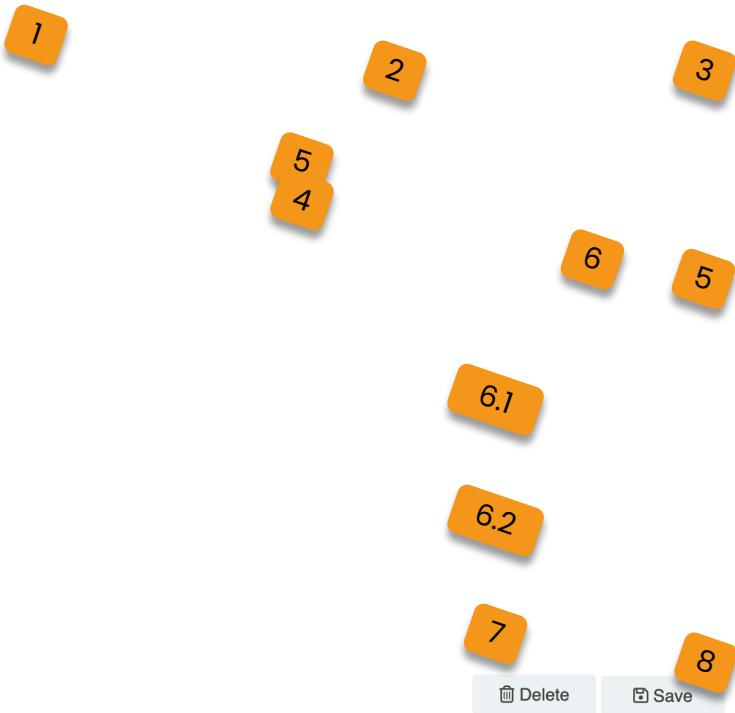
6.1

6.2

7

8

££



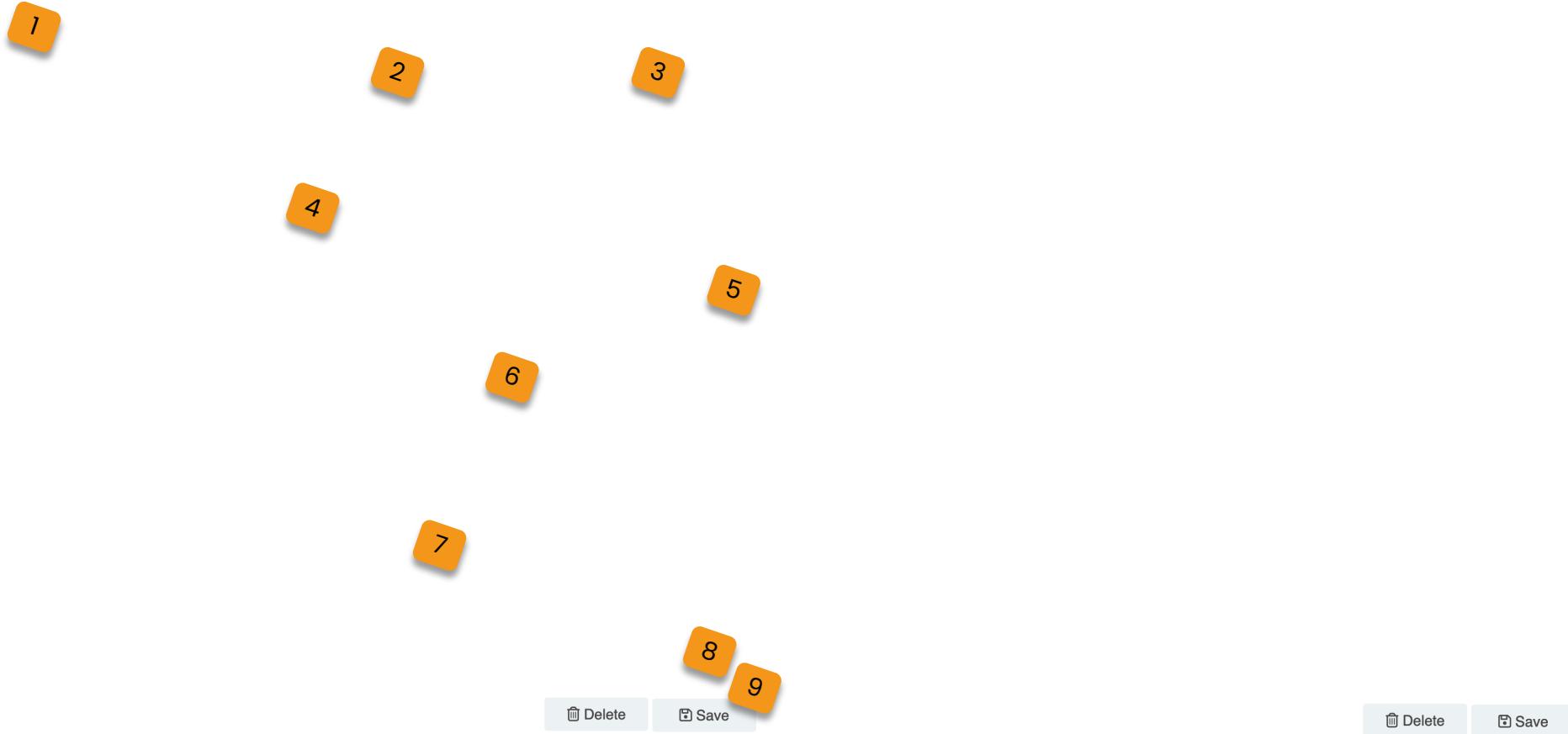
The screenshot shows the GAMS interface for configuring input widgets. The left sidebar has a dark theme with the following menu items:

- General settings
- Symbols
- Tables
- Input widgets** (highlighted with an orange box and number 1)
- Graphs
- Scenario analysis
- Database management

The main area is titled "Configure input widgets". It includes a navigation bar with tabs: "All symbols / widgets" (selected), "New GAMS option", and "New double-dash parameter".

The configuration form is as follows:

- Input symbol:** subcityselection (highlighted with an orange box and number 2)
- Select widget type:** Dropdown menu (highlighted with an orange box and number 3)
- Choose a label:** Region (highlighted with an orange box and number 4)
- Tooltip (optional):** Based on your selection, different cities will be included in the optimization. (highlighted with an orange box and number 5)
- Choices to select from:** Metropolises, North, East, South, West (highlighted with an orange box and number 6)
- Aliases for choices (optional):** (empty input field)
- Default value:** Metropolises (highlighted with an orange box and number 7)
- Checkboxes:**
 - Communicate as element text with GAMS (highlighted with an orange box and number 8)
 - Expand to multidropdown menu when submitting Hypercube jobs (highlighted with an orange box and number 9)
- Buttons:** Delete (disabled), Save (disabled).



The screenshot shows the GAMS interface with a dark sidebar and a light main panel. The sidebar includes options like General settings, Symbols, Tables, Input widgets (highlighted with a yellow box and number 1), Graphs, Scenario analysis, and Database management. The main panel is titled 'Configure input widgets' and contains the following fields:

- Input symbol:** subcityselection (highlighted with a yellow box and number 2)
- Select widget type:** Dropdown menu (highlighted with a yellow box and number 3)
- Choose a label:** Region (highlighted with a yellow box and number 4)
- Tooltip (optional):** Based on your selection, different cities will be included in the optimization. (highlighted with a yellow box and number 5)
- Choices to select from:** Metropolises, North, East, South, West (highlighted with a yellow box and number 6)
- Aliases for choices (optional):** (empty field)
- Default value:** Metropolises (highlighted with a yellow box and number 7)

At the bottom, there are two checkboxes: Communicate as element text with GAMS (highlighted with a yellow box and number 8) and Expand to multidropdown menu when submitting Hypercube jobs (highlighted with a yellow box and number 9). Below the checkboxes are 'Delete' and 'Save' buttons.

Configure input widgets

All symbols / widgets New GAMS option New double-dash parameter

Input symbol 2 **Select widget type** 3

Choose a label 4

Tooltip (optional) 5

Choices to select from 6

Aliases for choices (optional)

Default value 7

Communicate as element text with GAMS 8

Expand to multidropdown menu when submitting Hypercube jobs 9

Delete Save