SYSTEM-OF-SYSTEMS THAT ACT LOCALLY FOR OPTIMIZING GLOBALLY

EU FP7 - SMALL/MEDIUM-SCALE FOCUSED RESEARCH PROJECT (STREP)
FP7-ICT-2013.3.4: ADVANCED COMPUTING, EMBEDDED AND CONTROL SYSTEMS
D) FROM ANALYZING TO CONTROLLING BEHAVIOUR OF SYSTEM OF SYSTEMS (SOS)

2nd Consortium Meeting

Local4Global Traffic Control Case

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LOCAL4GLOBAL

Local4Global

Contact Information

For information regarding this Project: Check the Project Web-Site: http://local4global-fp7.eu

	Participants
1	CERTH - Centre for Research and Technology
2	ETHZ – Eidgenössische Technische Hochschule Zürich
3	RWTH – RWTH Aachen University
4	IK4 – IK4 TEKNIKER
5	TUC – Technical University of Crete
6	TRV – TRANSVER GmbH
7	TUM – Technische Universtität Muenchen

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FP7-ICT-2013.3.4: ADVANCED COMPUTING, EMBEDDED AND CONTROL SYSTEMS
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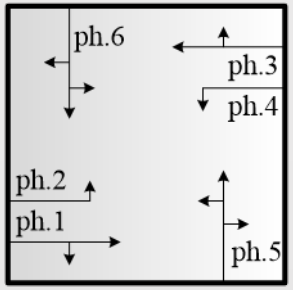
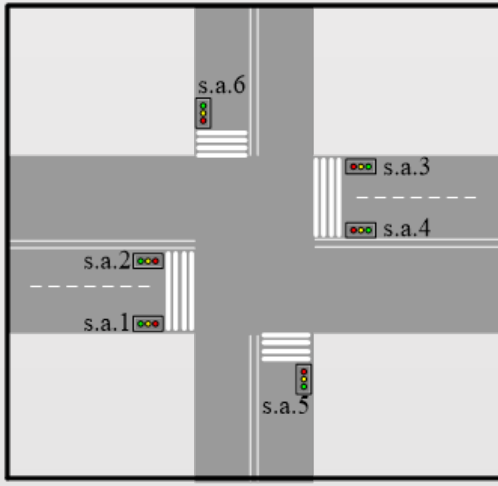
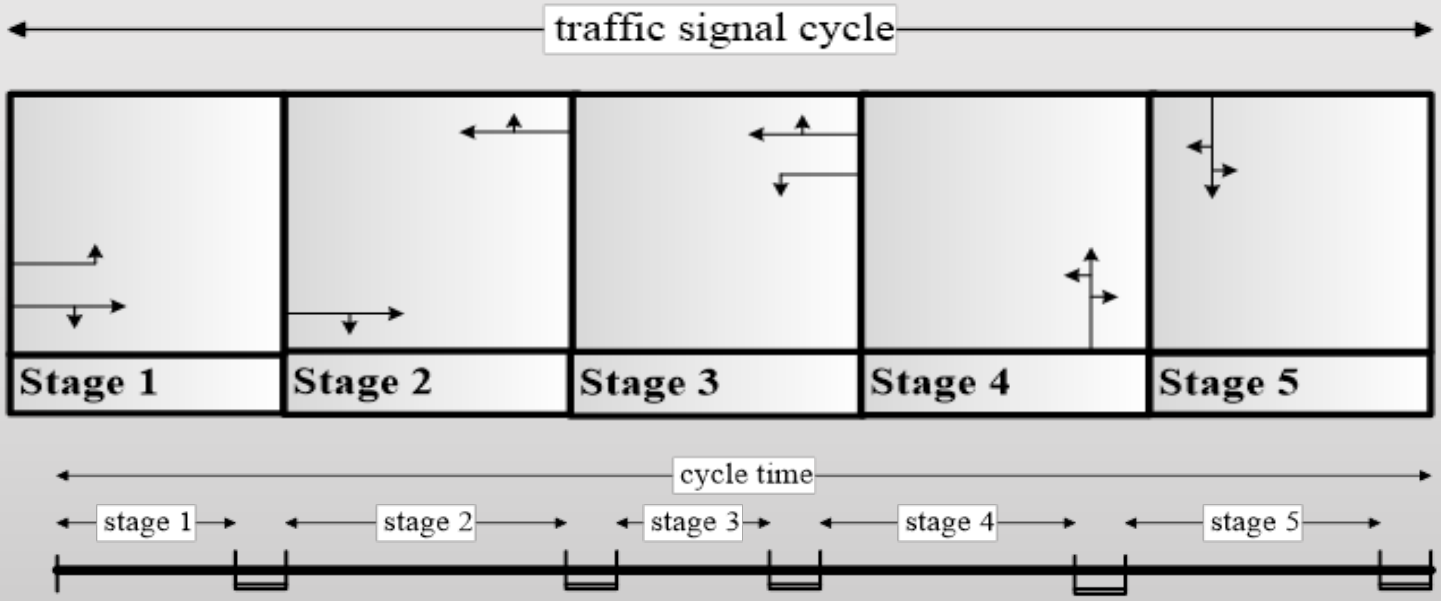
Discussion items

- Signal control basics
- The max pressure (MP) control algorithm
  - Pressure calculation
  - Transforming pressure in green
  - Matching produced plans with available for L4G application
- Max pressure investigations
  - Network and demand scenarios
  - Control cases
- Investigation results
  - Network performance
  - Remarks
- Next steps

Signal control basics







MP control algorithm: Pressure calculation (Kouvelas et al, 2014)

$$P_{j,i}(k_j) = \max\left\{0, \sum_{z \in v_{j,i}} p_z(k_j)\right\}, i \in F_j$$

$$p_z(k_j) = \left[\frac{x_z(k_j)}{x_{z,max}} - \sum_{w \in O_j} \frac{t_{z,w} x_w(k_j)}{x_{w,max}}\right] \cdot S_z, z \in I_n$$ (the subtracted term is 0 for destination links)

where

- j : signal-controlled urban junction
- I_j, O_j : set of links entering and leaving junction j, respectively
- k_j : current control period at junction j; control period may equal to a fixed cycle C_j
- F_j : set of stages of signal cycle at junction j
- $i \in F_j$: stage of junction's j signal cycle
- $v_{j,i}$: set of links $z \in I_n$ that receive r.o.w. during stage $i \in F_j$
- z, w : link indices
- S_z : saturation flow of link z (in veh/h)
- $x_z(k_j), x_w(k_j)$: number of vehicles within links z, w, respectively, at control period k_j (in veh)
- $x_{z,max}, x_{z,max}$: storage capacities of links z, w, respectively (in veh)
- $t_{z,w}$: turning rate from link z to link w
- $p_z(k_j)$: pressure of link z to all stages where $z \in v_{j,i}$ holds (in veh/h)
- $P_{j,i}(k_j)$: the pressure of stage $i \in F_j$ at the control of junction j (in veh/h)

MP control algorithm: Transforming pressure in green

- Given
  - $g_{j,i,min}$ the minimum permissible green times for stages i of junction's j signal cycle (in sec),
  - L_j the total lost time of signal cycle of junction j (in sec), and
  - Pressures $P_{j,i}(k_j)\ \forall\ i \in F_j$ (in veh/h)
- Calculate initial and final green times, $G_{j,i}(k_j)$ and $g_{j,i}(k_j)$ as follows:
  - Set $G_j = C_j - L_j$ and apply
  - $G_{j,i}(k_j) = \frac{P_{j,i}(k_j)}{\sum_{x \in F_j} P_{j,x}(k_n)} G_j$
  - TUC constraints application algorithm

MP control algorithm: Matching produced plans with available for L4G application

$\forall j$, given $g_{j,i}(k_j)$ $\forall i \in F_j$ calculated via MP algorithm:

Find the available signal plan $p^* \in P_j$ for which

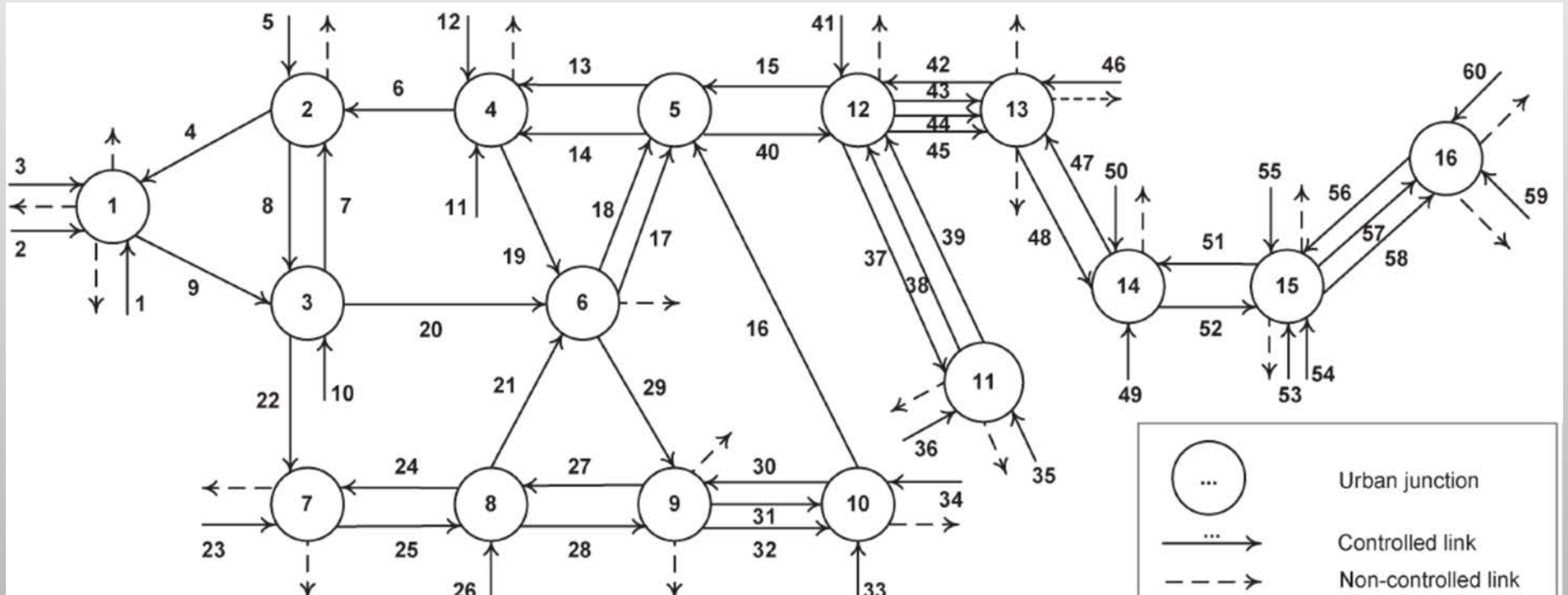
$$\psi = \sum_{i \in F_j} \left(g_{j,i} - g_{j,i}^{p} \right)^2 \rightarrow Min_p$$

where

- $g_{j,i}^{p}$ is the green duration of stage i of junction's j available signal plan $p \in P_j$ and
- P_j the set of all available plans for junction j

Max-pressure investigations: Network and demand scenarios

- Urban network
  - City of Chania, Greece
  - 16 junctions, 61 links, 42 stages
- A medium-loaded 5-hours demand scenario used in past TUC's strategy investigations; no demand during last hour



Max-pressure investigations: Control cases

- Reference case: Fixed time signal control with cycle time 90 s
- TUC: TUC split control
- MP1: Max-pressure; for zero pressures, nominal plan is applied
- MP2: Max-pressure; for zero pressures negative values are transformed to rates in the range [0,1]
- MP3: MP2 without downstream pressures (pure local MP application)

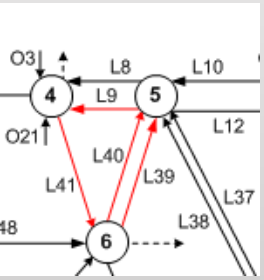
Investigation results: Network performance

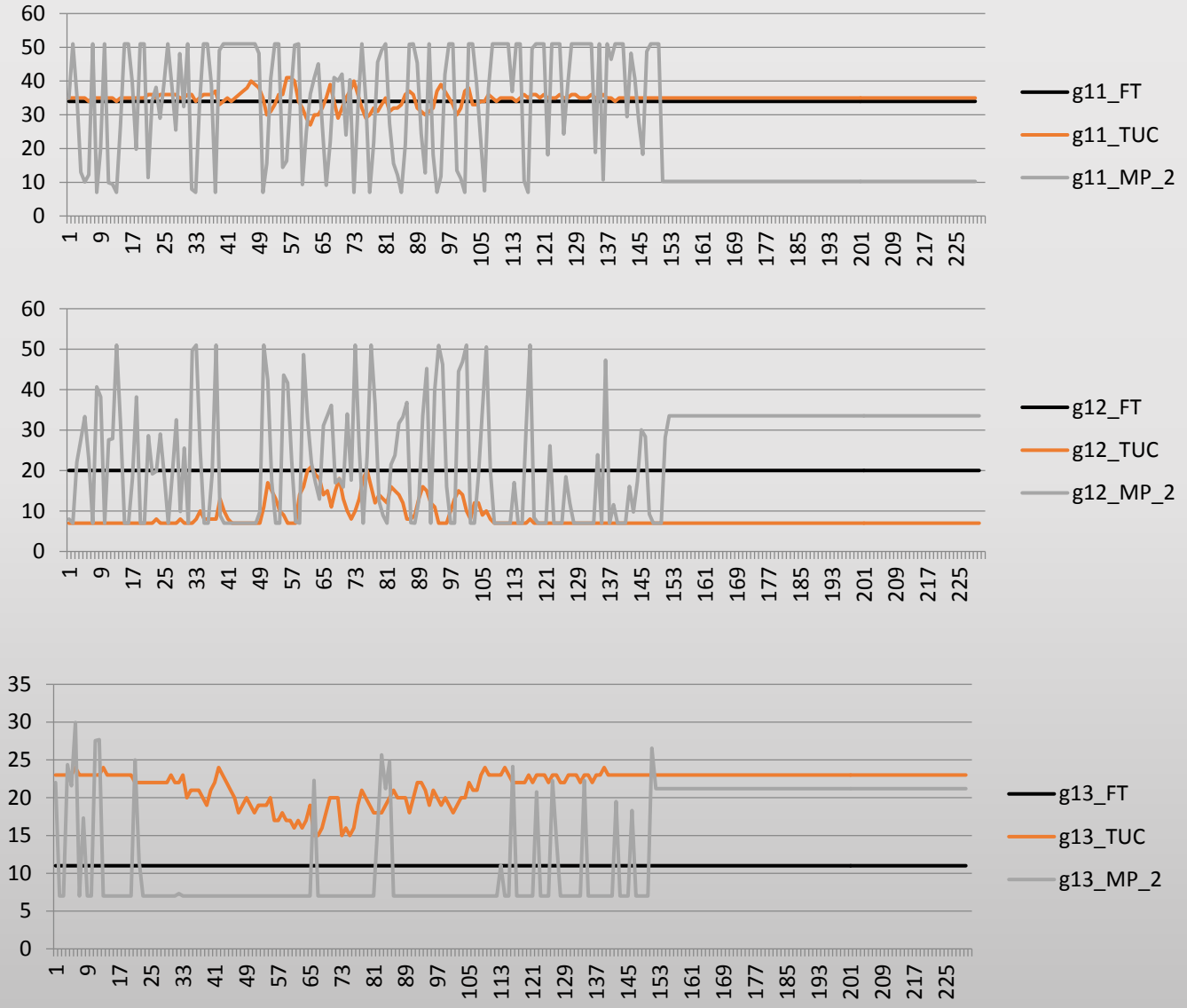
Control cases	Delay time per vehicle (s/km)	% change	Stop time per vehicle (s/km)	% change
Fixed time	305.25	n.a.	284.84	n.a.
TUC	274.82	– 9.97	253.56	– 10.98
MP1	288.59	– 5.46	265.86	– 6.31
MP2	275.71	– 9.68	253.38	– 11.04
MP3	**256.49**	**– 15.97**	**235.40**	**– 21.00**

Investigation results: Remarks (1)

Zoom in junction 5 (a crucial one)

- 5 links
- 3 stages
  - Stage 1: L10, L39
  - Stage 2: L39. L40
  - Stage 3: L37, L38

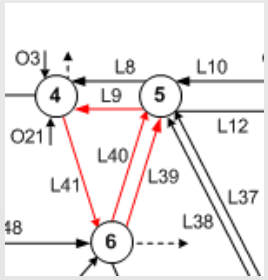


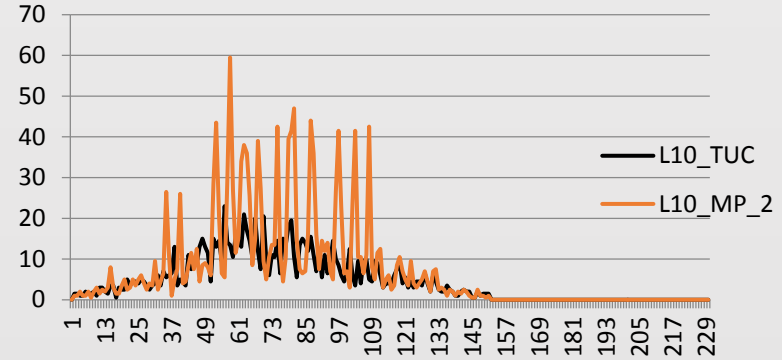


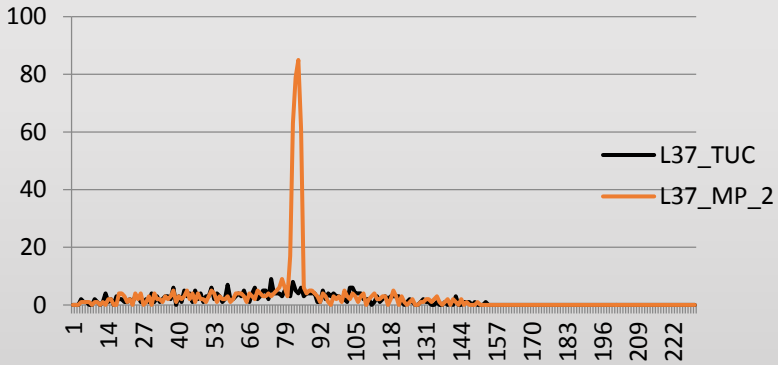
Investigation results: Remarks (2)

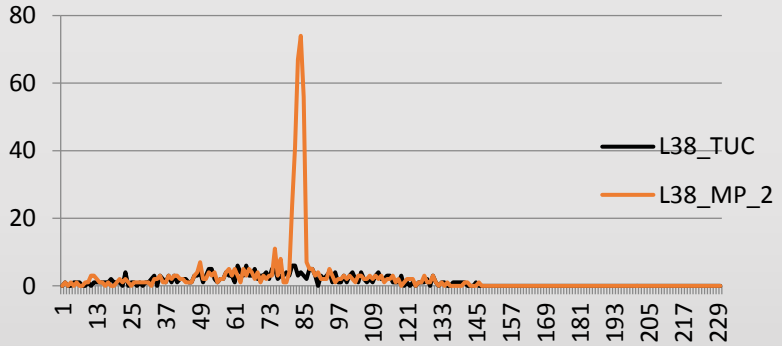
Occupancy diagrams of junction 5

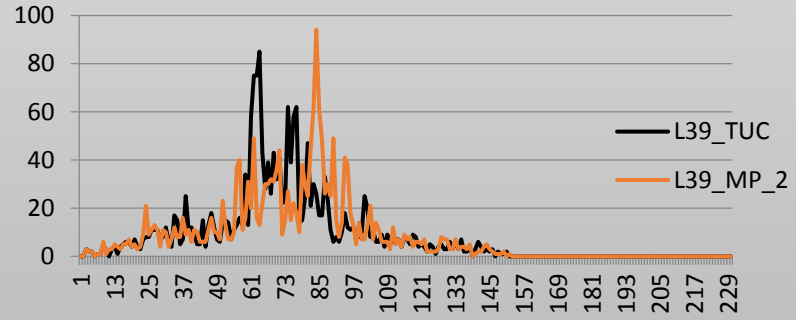
- 5 links
- 3 stages
  - Stage 1: L10, L39
  - Stage 2: L39. L40
  - Stage 3: L37, L38

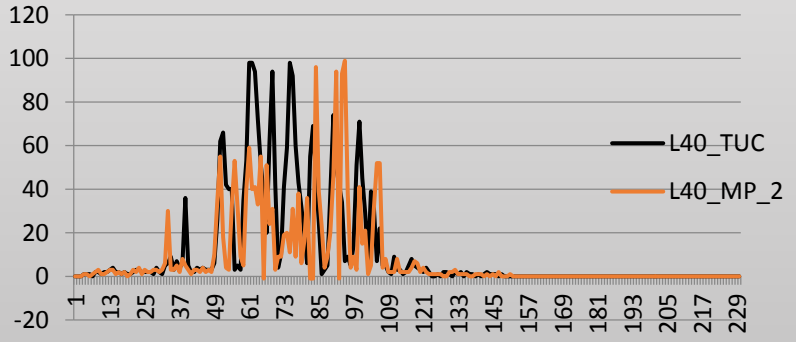












The increased green split oscillations result in increased occupancy oscillations

Next steps

- To further investigate and fine-tune max-pressure
  - Further investigate performance under pure isolated operation (i.e. MP3)
  - Investigate performance adding upstream forthcoming pressure
  - Investigate performance under more demand scenarios
- Integration with Local4Global control concept via parameters that affect the green splits provided by the local control
- Clarification of application requirements as far as both the particular Local4Global case study and the overall Local4Global concept are concerned:
  - How much “local” the local strategy would be?
  - Software implementation (simulation vs real-life application oriented)
  - Cycle/offset control
  - Network description/data (signal cycle structure, measurements, etc.)

References

Kouvelas A, Lioris J, Fayazi SA, Varaiya P (2014). Max-pressure controller for stabilizing the queues in signalized arterial networks. TRB Annual Meeting.

TUC / DSSL

Leader of WP2, Task 2.1 and D2.1

- The Technical University of Crete (TUC) was founded in 1977 in Chania, Crete, Greece, with the mission to develop modern engineering specialties, place emphasis on research in fields of advanced technology, and establish close cooperation with the industry and other production organizations in Greece (www.tuc.gr)
- The Dynamic Systems and Simulation Laboratory (DSSL) is the particular TUC's unit involved in Local4Global project. DSSL (www.dssl.tuc.gr):
  - Belongs to the section of Decision Systems of the School of Production Engineering and Management, was founded in 1988, and has been headed since 1994 by Prof Markos Papageorgiou
  - Has profound knowledge and broad experience in the theories of modelling, simulation, statistics, optimisation, automatic control, and their practical application to traffic and transportation systems, water networks, production systems, and further areas
  - Has been involved in numerous research and demonstration projects at a national, European and international level, gaining a remarkable experience through the implementation, testing, and evaluation of its several techniques and tools in real conditions
  - Will bring all the knowledge and experience in Local4Global and will gain by extending its perspectives in several respects

TUC – Key people involved

- Prof. Markos Papageorgiou

  - Person in charge of scientific and technical/technological aspects
  - WP2 Leader
  - Member of the Steering Committee

- Prof. Ioannis Papamichail

  - Contact person for administrative, financial and legal matters
  - RTD

- Dr. Christina Diakaki

  - Contact person for scientific and technical/technological aspects
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- Dr. Diamantis Manolis

  - RTD

Questions?

Thank you!