Polytechnic of Bari

Department of Electrical and Information Engineering

DECISION & CONTROL LABORATORY
Research Activities

http://dclab.poliba.it/

mariagrazia.dotoli@poliba.it

People

Scientific Coordinator

Prof. Engr.
Mariagrazia DOTOLI

Post-doc research fellows

Dr. Engr. Raffaele
CARLI

Dr. Engr. Graziana
CAVONE

Phd students

Engr. Seyed M.
HOSSEINI

Engr. Paolo
SCARABAGGIO

Engr. Lucilla
DAMMACCO

Engr. Silvia
PROIA

Engr. Giulia
TRESCA

Engr. Bahman
ASKARI

Webpage:
http://dclab.poliba.it

Politecnico di Bari

D&C Lab

Decision and Control Laboratory

- MISSIONS:
  - Fostering the **education of undergraduate/graduate students**,
  - Supporting **courses lab activities**,
  - Performing **theoretical/applied research** in **systems, control, optimization, and decision-making areas**.

Decision and Control Laboratory

❑ COLLABORATIONS:

- **Universities**: University of Cagliari (**Italy**), Ecole Centrale de Lille (**France**), Aix-Marseille Université (**France**),Hamburg Helmut Schmidt University (**Germany**), University of Manchester (**UK**), Chalmers University (**Sweden**), Universidad Zaragoza (**Spain**), New Jersey Institute of Technology of Newark (**USA**), Delft University of Technology (**Holland**), Politechnika Krakowska (**Poland**), Université de Lorraine (**France**).

- **Public companies**: Banque Central du Luxembourg, Ferrovie del Sud Est, Municipality of Bari, ReteGas Bari SpA, AMTAB SpA.

- **Private companies in Italy**: Centro Ricerche Fiat, IBM, Enel Distribuzione, Elettric80 SpA, Masmec SpA, Mermec SpA, General Transport Service SpA, MacNil Srl, Planetek Italia Srl, Divella SpA, Le Gemme, Tera Srl, Cannillo Srl, SimNT Srl, Primadonna SpA, Veronico Srl, Dream Project SpA, Gigant Italia Srl.

Decision and Control Laboratory

- RECENT RESEARCH AREAS
  - **Networked systems**
    - epidemic models
    - social networks
  - **Smart Cities**
    - Smart management
    - Smart energy
    - Smart mobility
  - **Industry 4.0**
    - Smart manufacturing
    - Digital Twin,
    - Virtual Reality,
    - Collaborative Robotics
  - **Transport and Logistics**
    - Passengers transport
    - Freight transport
    - Logistics 4.0

Networked Systems

- Epidemic models
- Social network

Epidemic models

- Since the end of 2019, the SARS-CoV-2 coronavirus has caused more than 2.5 million deaths and 110 million of confirmed cases, thus resulting the most impacting pandemic in the recent decades.
- Currently vaccinations have not yet lead to mass coverage, hence, the main control actions still rely on non-pharmaceutical interventions (NPIs), such as mobility restrictions and social distancing.

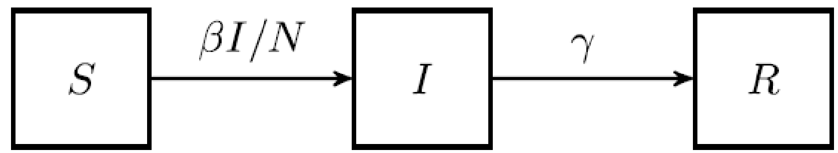
The first fundamental mathematical model for epidemic diseases was formulated by Kermack and McKendrick in the early 20th century [Kermack and McKendrick, 1927].

This was the first compartmental model applied to epidemic modeling!

Epidemic models

Susceptible-Infectious-Removed (SIR) model –> useful for single-wave epidemics with natural immunity (e.g., measles, mumps, rubella).

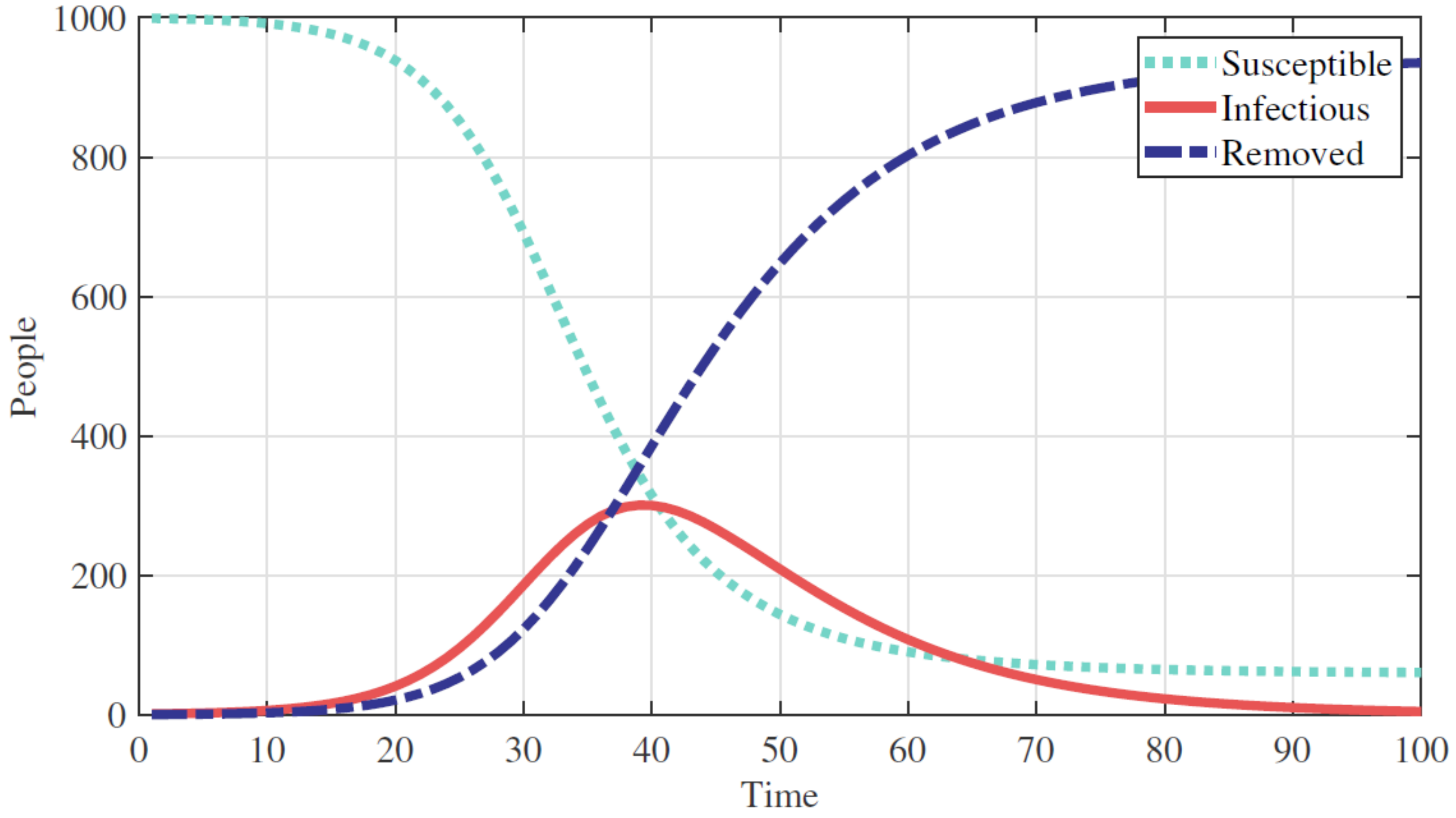
$$\frac{dS}{dt} = -\frac{\beta IS}{N}$$
$$\frac{dI}{dt} = \frac{\beta IS}{N} - \gamma I$$
$$\frac{dR}{dt} = \gamma I$$



- S: Number of Susceptible individuals
- I: Number of Infectious individuals
- R: Number of Removed/Recovered individuals (immune or dead)
- β: Infection rate
- γ: Removing rate
- N: Total population size: $N = S(t) + I(t) + R(t)$.

Epidemic models

Example with $\beta = 0.3$, $\gamma = 0.1$, $N = 1000$, $I(0) = 1$ and $R(0) = 0$.



Epidemic models

How we can simply evaluate epidemics? –> basic reproduction number

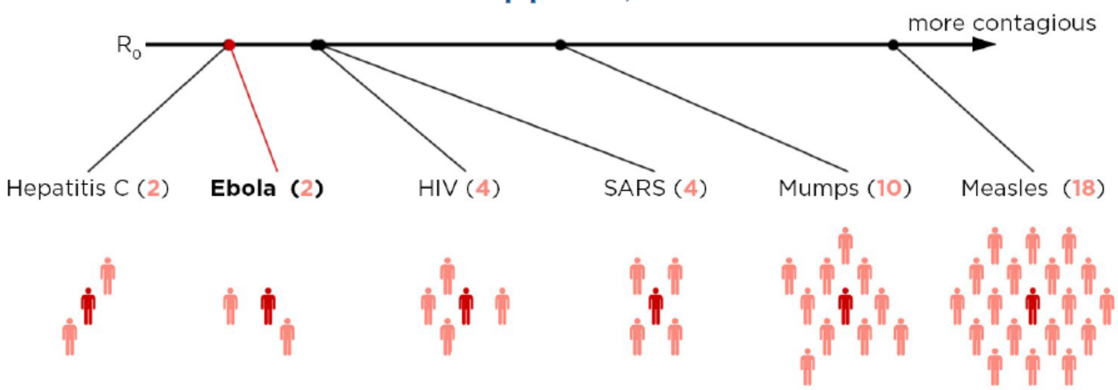
Definition

The basic reproduction number R_0 is the number of secondary infections that a single infected person ($I(0) = 1$) would produce in a fully susceptible ($S = N - 1$) population through the entire duration of the infectious period.

For the SIR model, R_0 is defined by the following ratio:

$$R_0 = \frac{\beta}{\gamma}$$

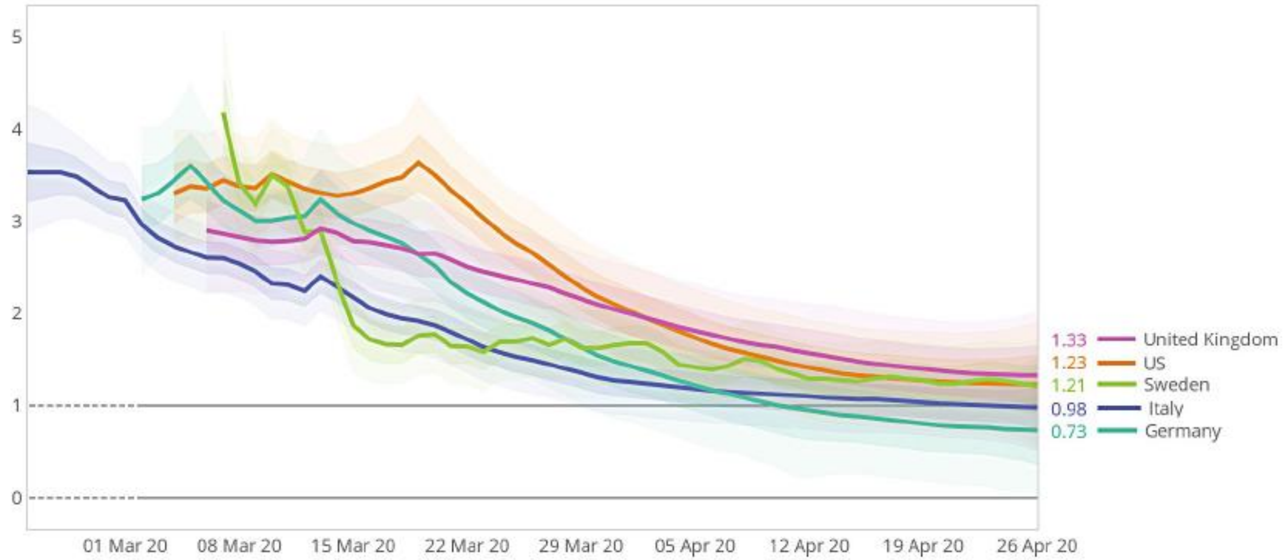
For COVID-19, the basic reproduction number R_0 is estimated between 2 and 6 (when no restrictions are applied).



Epidemic models

So how can an epidemic be controlled?

1. Reduce S: vaccination (heard immunity).
2. Reduce β: wash hands, isolate sick persons, shut down public events, close schools (enforce the decrease of R_0 over time, such that $R_0 < 1$).
3. Increase γ: better and faster clinical treatments, antivirals (enforce the decrease of R_0 over time, such that $R_0 < 1$).

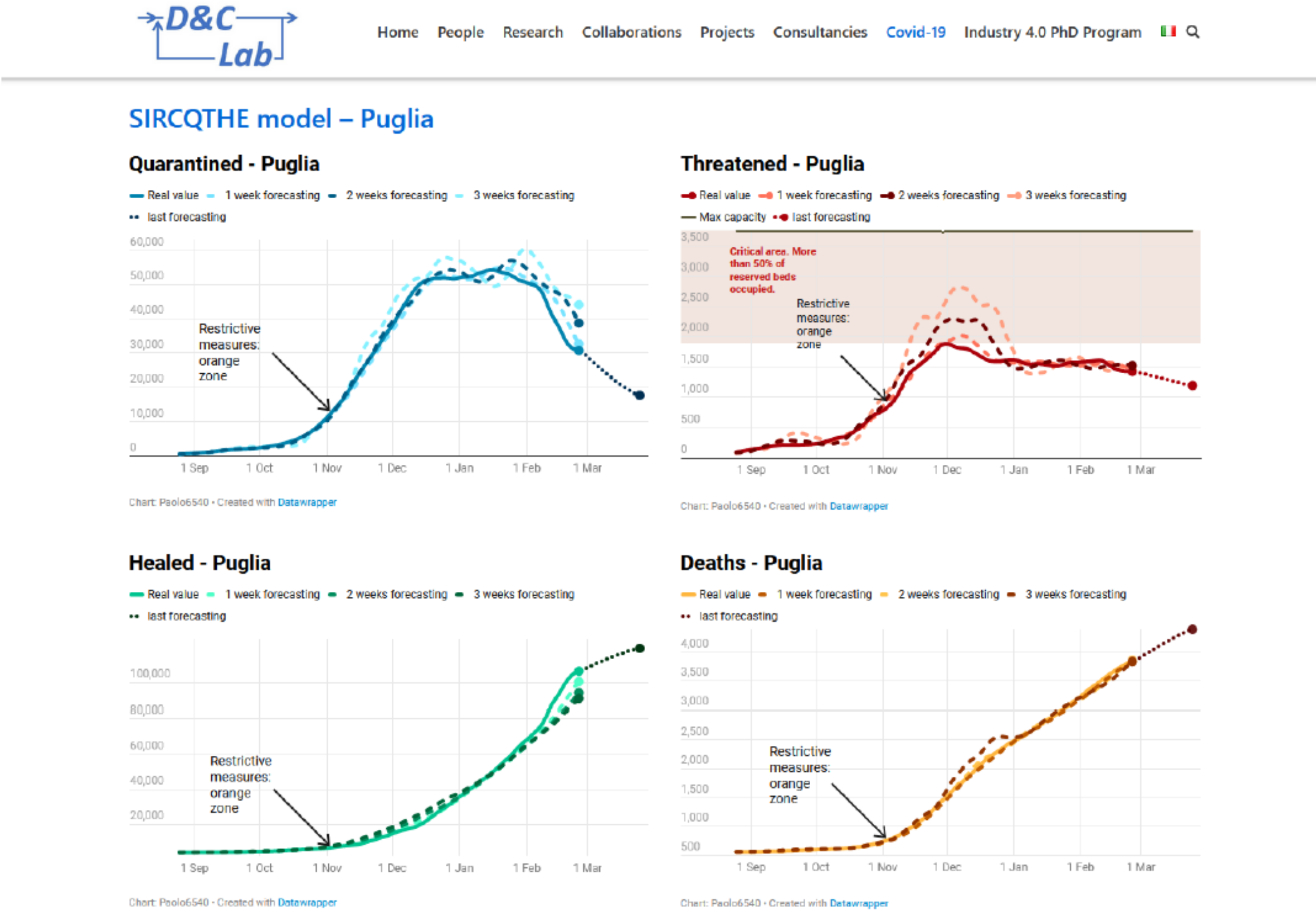


Variation of the COVID-19 R_0 parameter in different countries for the first two months of the pandemic during the lockdown.

Epidemic models

D&C Lab Current Dashboard (24 August - present)

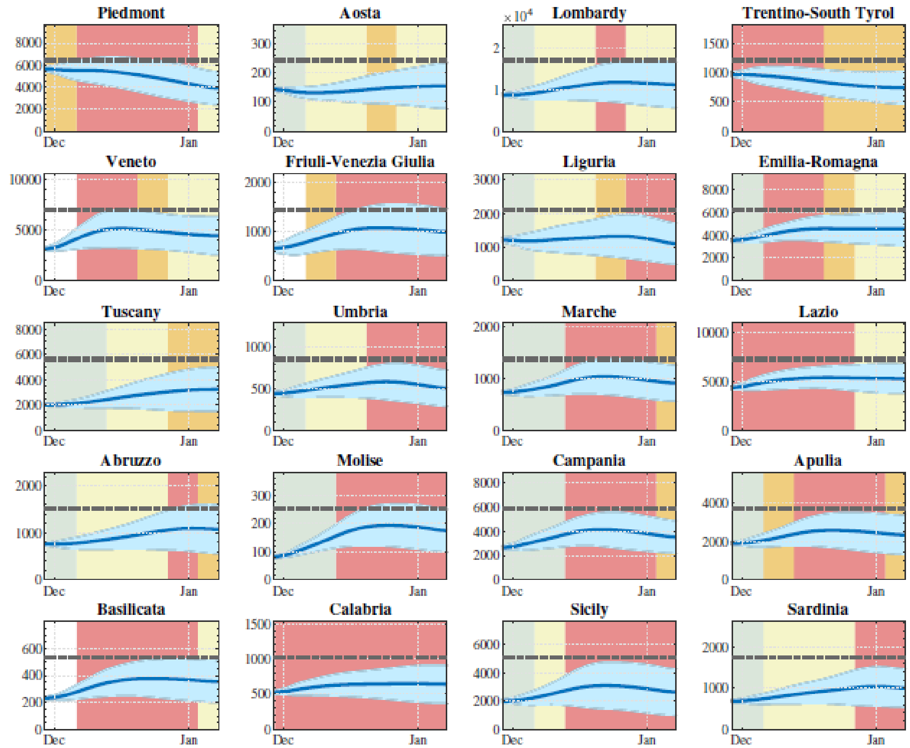
Interactive charts for the *SIRCQTHE* model



Epidemic models

Predictive control of Non-Pharmaceutical Interventions

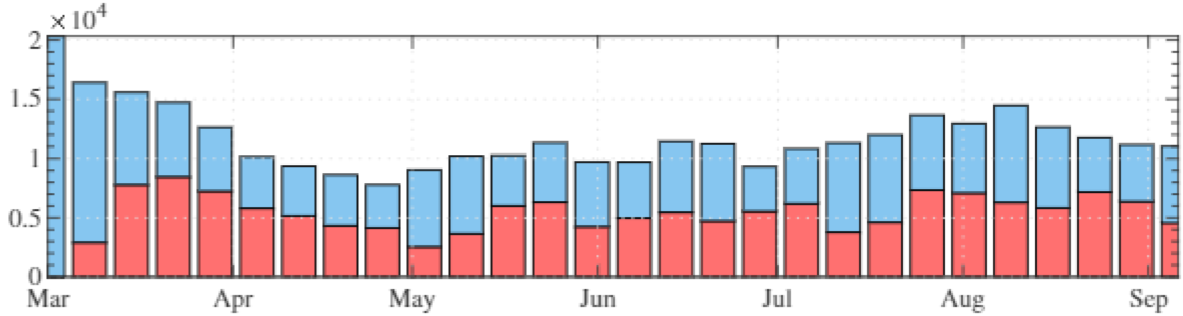
Simulation start: 5 december.



Results of the Monte Carlo simulation in terms of Threatened cases over the 6 weeks control/prediction horizon: expected Threatened (blue line), confidence interval for the Threatened cases (cyan area), maximum number of Threatened cases (black dotted line), and the evolution of the control action in the control horizon (different background colors).

Epidemic models

Optimal control of anti-covid-19multi-dose vaccine administration



Vaccine doses distribution over the simulation horizon: first doses (blue) and second doses (red)

Social networks

Motivations

- A social network is a structure composed by a group of interconnected independent agents.
- These networks are essential for the spread of information, opinion, and innovation.
- The spread of influence is related to the "word-of-mouth" process
  - This diffusion process is essential for viral marketing, personalized recommendation, and target advertisement.

Objective of the work –> Propose a novel low-complexity and highly accurate algorithm to maximize the spread of influence in large-scale networks.

Social networks

Definition

Social network: a direct graph $\mathcal{G} = (\mathcal{V}, \mathcal{E})$, where $\mathcal{V}$ is the set of nodes with cardinality $N = |\mathcal{V}|$ representing people, and $\mathcal{E} \in \mathcal{V} \times \mathcal{V}$ is the set of edges describing the social connections between pairs of people.

Definition

$N_j^{in} = \{i \in \mathcal{V} | (i,j) \in \mathcal{E}\}$ are the in-neighbors of node j and $N_j^{out} = \{i \in \mathcal{V} | (j,i) \in \mathcal{E}\}$ are the out-neighbors of node j.

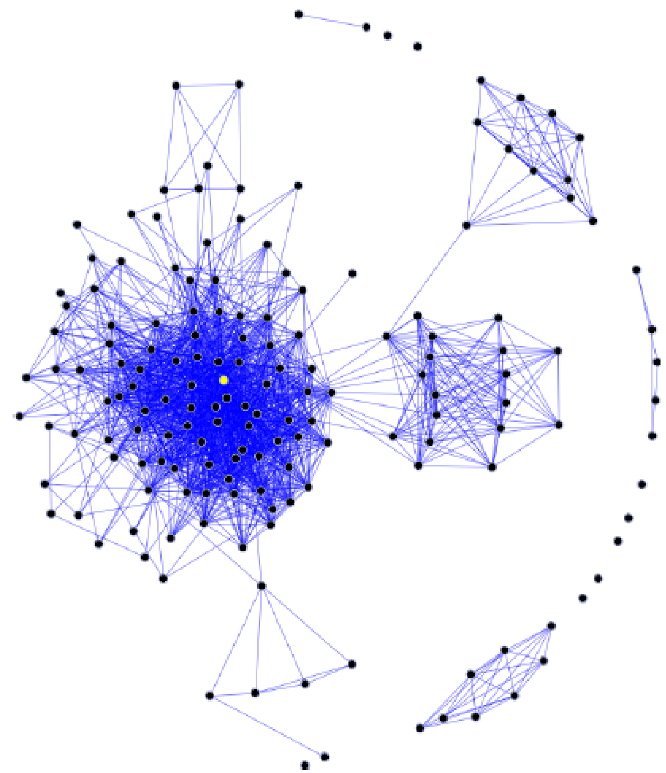


Figure 1: A social network graph [wikipedia.org]

Social networks

Definition

The problem is to find S initial nodes that maximize the influence spread through the network, i.e.:

$$\phi_0 = \underset{\phi \subseteq \mathcal{V}}{\operatorname{argmax}} \{\sigma(\phi) \,|\, |\phi| = S\} \tag{3}$$

where S is the chosen cardinality for the seed set.

Several algorithms are available to approximately solve the influence maximization (IM) problem:

- *SelectTopS algorithm*
- *Greedy algorithm*
- The novel proposed algorithm –> *Reduced Influence Overlap (RIO) algorithm*

Social networks

Email-Eu-core-Dept1 (309 nodes, 3031 edges)

- Email exchange across a large European research institution department, a directed edge i, j means that person i sent an email to person j.
- The results obtained by the *RIO* algorithm compare with the ones obtained by the *Greedy* algorithm, while requiring approximately the (lower) computational time of the *SelectTopS*.

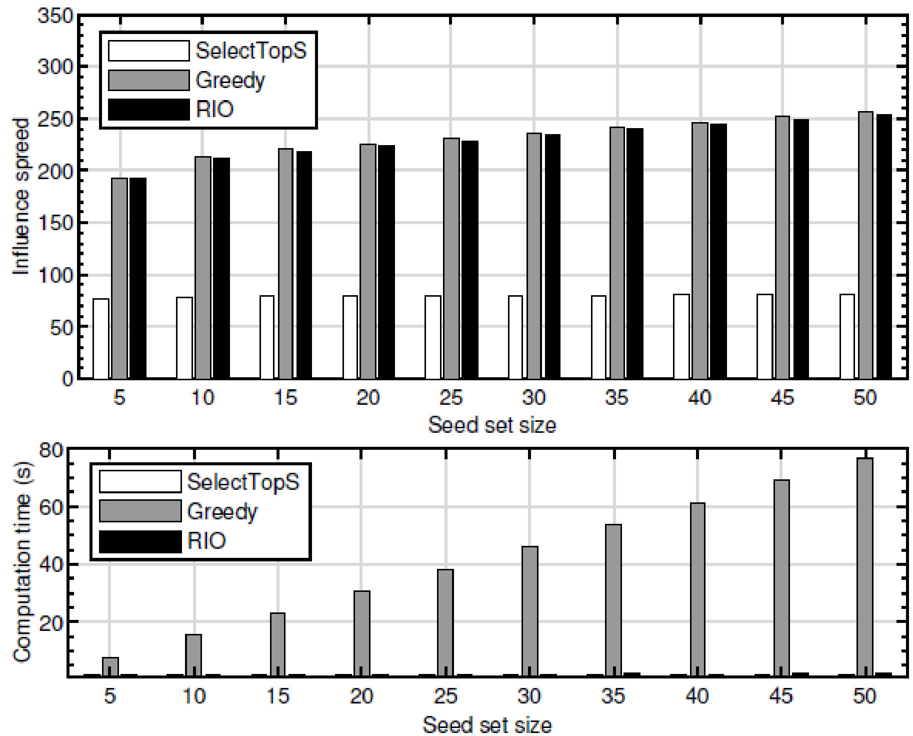


Figure 2: Email-Eu-core-Dept1 dataset: influence spread (a) and computation time (b) computed by the *SelectTopS*, *Greedy*, and *RIO* algorithms.

Smart Cities

- **Energy efficiency**
  - «Res Novae» Project
  - «UCCSM» Project

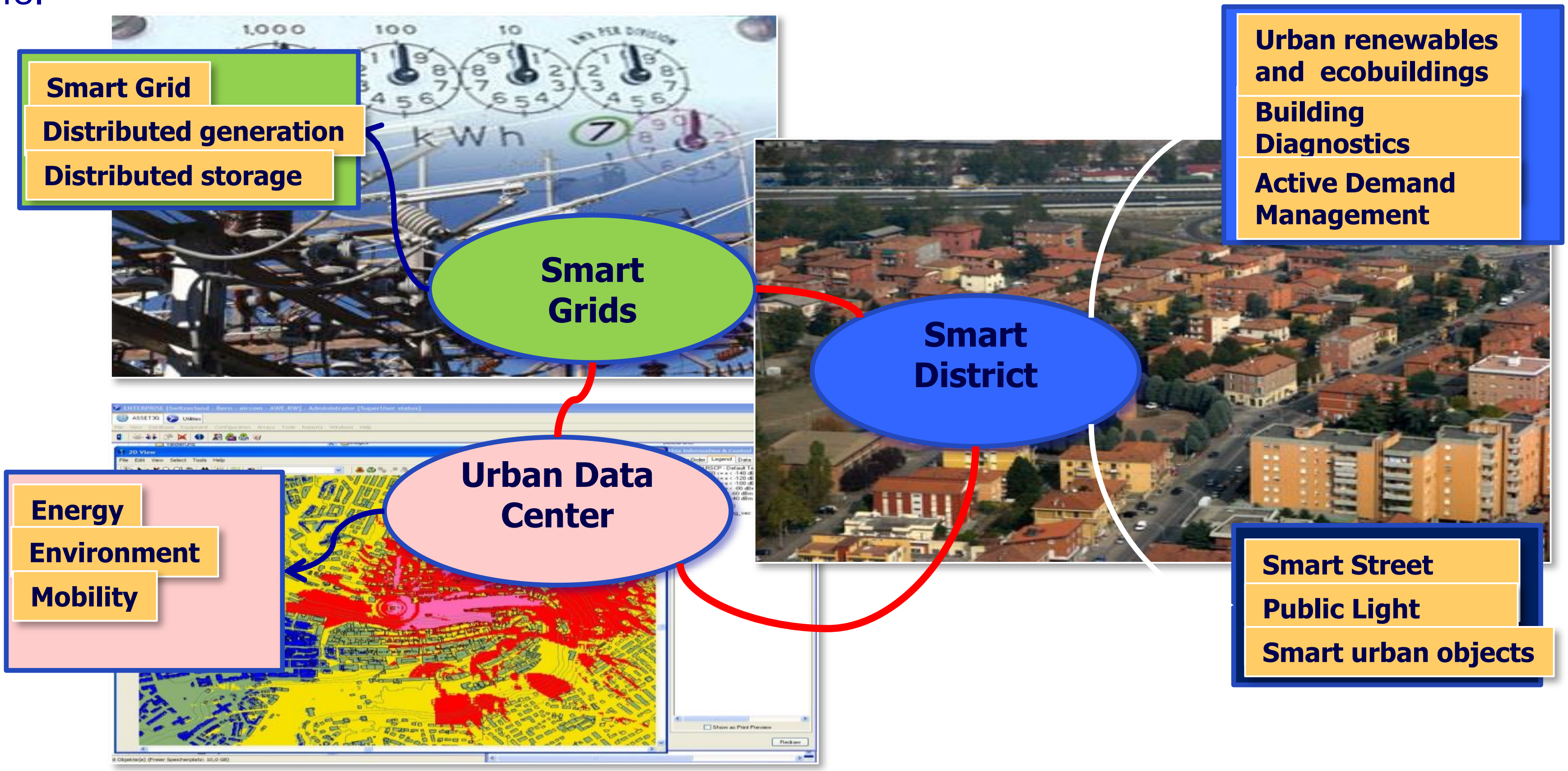
- **Smart mobility**
  - «Semina» Project

RES NOVAE Project

(Reti Edifici Strade Nuovi Obiettivi Virtuosi per l’Ambiente e l’Energia)

Networks, buildings, roads: new virtuous objectives for the environment and energy

Aim: Develop an **integrated urban planning** solution to increase city performance in terms of energy efficiency and environmental sustainability while meeting citizens’ expectations for quality of life.



UCCSM Project

(Urban Control Center per le Smart city Metropolitane)

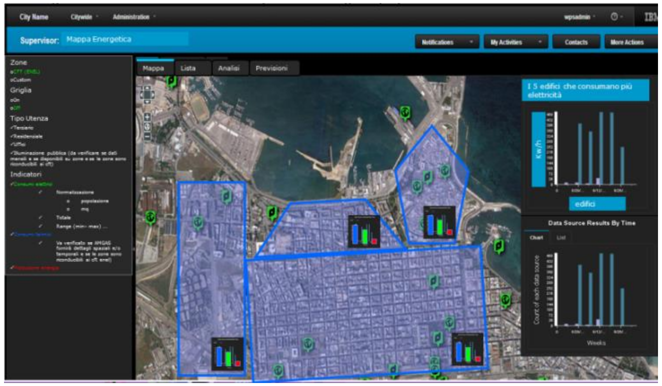
Urban Control Center for the metropolitan smart cities

uccsm

Aim: create a platform for **monitoring and managing** urban dynamics and city performance, to support the energy governance for **Public Administrations** and to enable communication to **citizens** and participation of **communities**.

Advantages:

- *Indicators dashboard*: report and analysis of urban performance (status, history, predicted state).
- *Business intelligence* tools for *strategic* decision making and *planning* of urban sectors.
- Collaboration tool for *citizens' awareness* and *active involvement.*

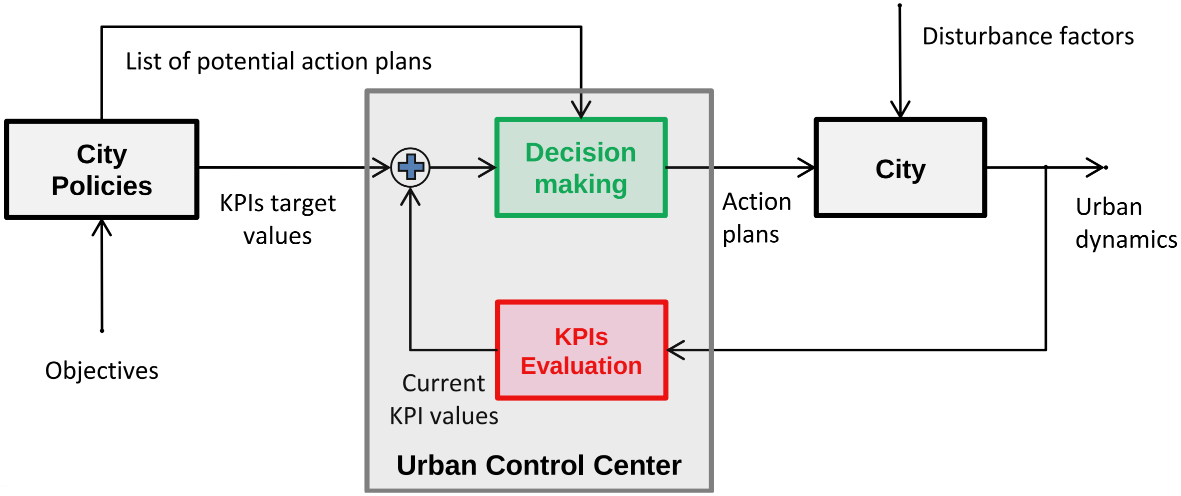


Monitoring, management, and control of smart cities

➢ Tools for developing smart cities

Two main functionalities are presented for smart cities monitoring and management:

- the measure and monitoring of the smart city performance
- the definition of **strategic action programs** as result of **decision making and planning**



1. Dashboard of KPIs

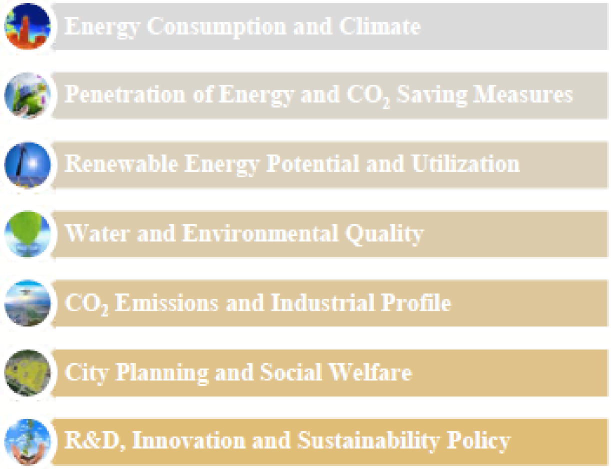
2. decision making support tools

smart city

Monitoring, management, and control of smart cities

➢ Benchmarking of metropolitan areas

Aim: Development of a **multi-criteria technique** to support the Public Administration in the **analysis** and **benchmarking** of the **sustainability** of energy/water/environment systems in metropolitan areas.



Methodology: AHP (Analytic Hierarchy Process)

- Case study:
  - 35 SDEWES (Sustainable Development of Energy, Water, and Environment Systems) indicators
  - Metropolitan City of Bari (Bari, Bitonto, Mola, Molfetta)

CITTÀ METROPOLITANA
DI BARI

Monitoring, management, and control of smart cities

➢ Planning

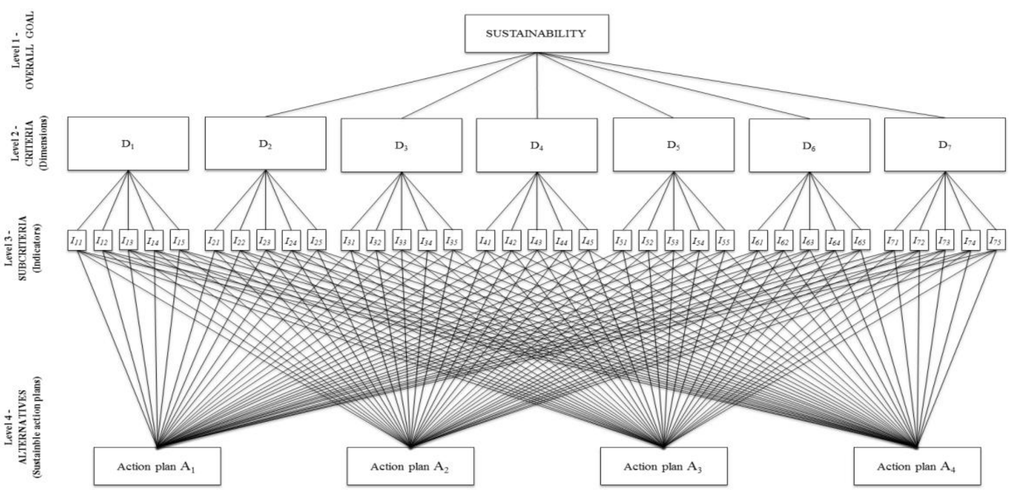
Aim: Define **strategic action plans** in metropolitan areas (*multi-criteria*, with *multiple decision makers*, under *uncertain* data).

Methodology: Fuzzy Analytic Hierarchy Process (FAHP) Group Decision Analysis

Case study:

- 35 SDEWES (Sustainable Development of Energy, Water, and Environment Systems) indicators
- Metropolitan City of Bari (11 strategic areas)
- 22 EU projects aggregated by budget in 4 action plans

CITTÀ METROPOLITANA
DI BARI



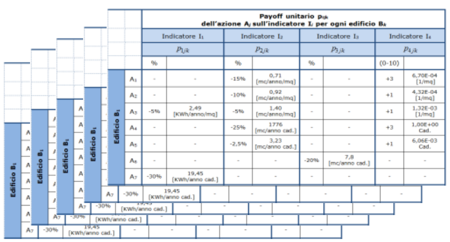
		Overall FAHP rate (Level 1 priority)
Planning alternatives	A_1	0.25063
	A_2	0.25362
	A_3	0.24500
	A_4	0.25074

Monitoring, management, and control of smart cities

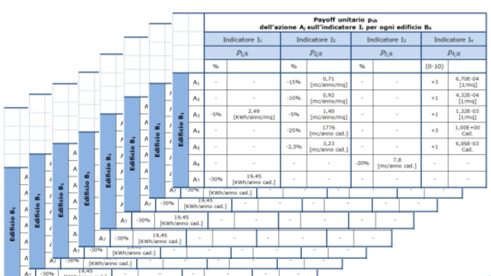
➢ Strategy for the multisectoral efficiency improvement

TOTAL BUDGET

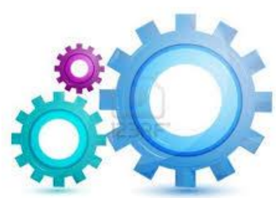
PAYOFFS AND COSTS FOR PUBLIC BUILDINGS PORTFOLIO



PAYOFFS AND COSTS FOR STREET LIGHTING SYSTEM



BLDP



OPTIMAL BUDGET ALLOCATION

OPTIMAL RETROFIT PLAN FOR STREET LIGHT. SYS.

Parameter		u_{st}									
Subsystem		1	2	3	4	5	6	7	8	9	10
Type	1	0	0	0	0	0	1	5	52	5	27
	2	27	0	0	0	0	2	18	2	24	18
Parameter		v_s									
Subsystem		1	2	3	4	5	6	7	8	9	10
		0	0	0	0	0	0	0	0	0	0
Parameter		w_s									
Subsystem		1	2	3	4	5	6	7	8	9	10
		1	1	1	1	1	1	1	1	1	1

OPTIMAL RETROFIT PLAN FOR PUBLIC BUILDINGS

		Action						
		A_1^{pb}	A_2^{pb}	A_3^{pb}	A_4^{pb}	A_5^{pb}	A_6^{pb}	A_7^{pb}
Building	B_1	0	0	0	1	1	1	1
	B_2	0	0	1	1	1	1	1
	B_3	0	1	0	1	1	1	1
	B_4	0	0	1	1	1	1	1
	B_5	0	0	1	1	1	1	1

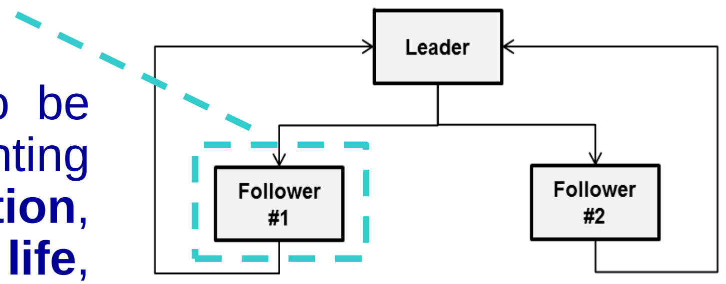
- Replacing half the lamps, dimming of all lamps.
- Roof thermal insul. B_2, new windows B_2, B_4, B_5.
- All buildings: new boilers, thermostatic radiator valves, water tap aerators, high efficiency lamps.

Monitoring, management, and control of smart cities

➢ Local decision-making panels

LDP #1 – Street Lighting Panel

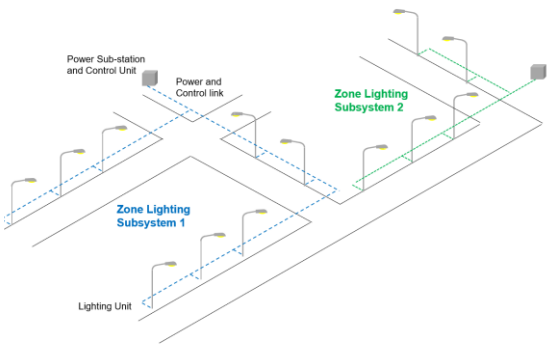
Aim: Determine the **optimal set of actions** to be implemented in the given existing street lighting system in order to reduce **energy consumption**, maintaining the required **comfort** and **quality of life**, protecting the **environment**, while not exceeding the given **budget** constraint.



Problema di Ottimizzazione LDP #1

Methodology: bi-level decentralized hierarchical constrained optimization.

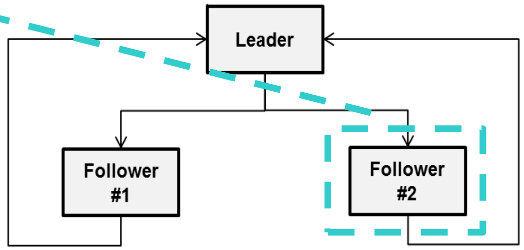
- Decision variables:
  - *Luminaire replacement*: u_{st} = quantity of lamps of the t-th type to be replaced in the s-th zone lighting subsystem
  - *Energy harvesting module installation*: v_s = quantity of energy harvesting devices to be installed in the s-th zone lighting subsystem
  - *Zonal dimming device installation*: w_s = binary variable of unit value if dimming has to be integrated in the control station of s-th zone lighting subsystem (zero otherwise)



➢ Local decision-making panels

LDP #2 – Public Buildings Panel

Aim: Determine the **optimal set of actions** to implement on buildings portfolio in order to make buildings more **energy efficient**, more **environmentally sustainable**, more **comfortable** for occupants, while not exceeding the given **budget** constraint.



Problema di Ottimizzazione LDP #2

Methodology: two-level binary multi-objective optimization

Criterion-dependent objective function

$$\max_{x^{(2)}} f_h^{(2)}\left(x^{(2)}\right) = \sum_{j=1}^{J}\sum_{k=1}^{K} x_{jk} \cdot p_{hjk} \quad \forall h = 1,\dots,H$$

Decision variables $x_{jk} = \begin{cases} 1 & \text{if action is applied} \\ 0 & \text{else} \end{cases}$

Criteria

Criterion-dependent payoff

s.t.

$$\sum_{j=1}^{J}\sum_{k=1}^{K} x_{jk} \cdot c_{jk} \le Y^{(2)}$$

Budget

Action cost

Energy Scheduling

➢ Energy scheduling for smart buildings / smart homes

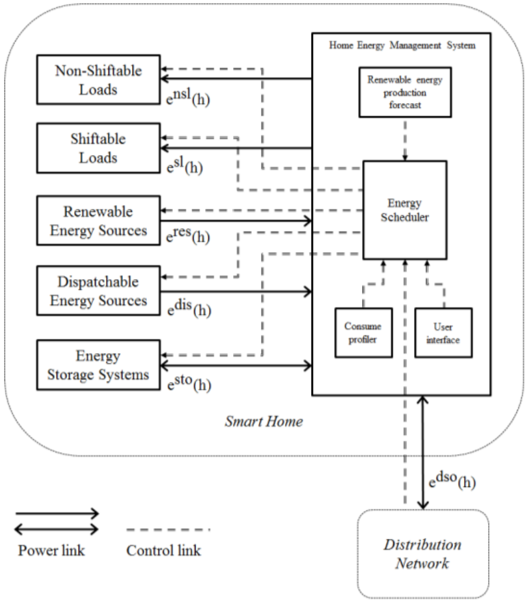
Aim: provide a **smart energy scheduling** for public (or private) buildings under uncertain data.

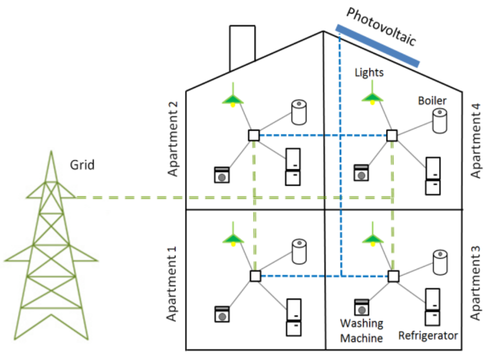
Methodology: constrained fuzzy optimization

The system comprises:

- *home appliances* (uninterruptible passive loads distinguished into non-shiftable and shiftable loads)
- *renewable energy sources* (photovoltaic or wind generators)
- *dispatchable energy sources* (microturbines or fuel cells)
- *energy storage systems* (batteries)

Advantages: full exploitation of the potential of local energy generation and storage to reduce the individual user *energy consumption cost* and *PAR* (Peak to Average Ratio)





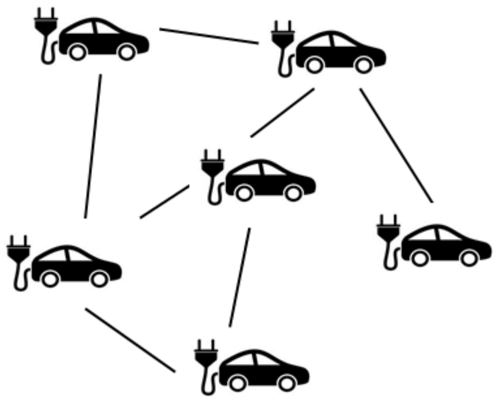
Energy Scheduling

➤ Energy scheduling for smart buildings / smart homes

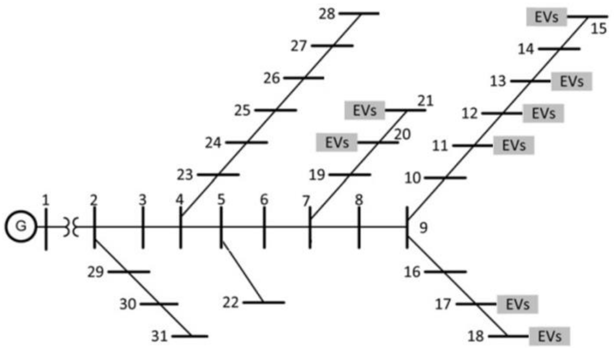
Aim: provide a **day-ahead scheduling technique for the optimal charging of a large-scale fleet of Electric Vehicles (EVs)**

.

Methodology: iterative distributed / decentralized algorithm based on duality, proximity, and consensus theory



Advantages: ensuring a cost-optimal profile of the aggregated energy demand, complying with the EV individual needs; satisfying the resource constraints depending both on power grid components capacity and EV locations in the distribution network; using a minimal information structure, where EVs locally communicate only with their neighbours, without relying on a central decision maker.



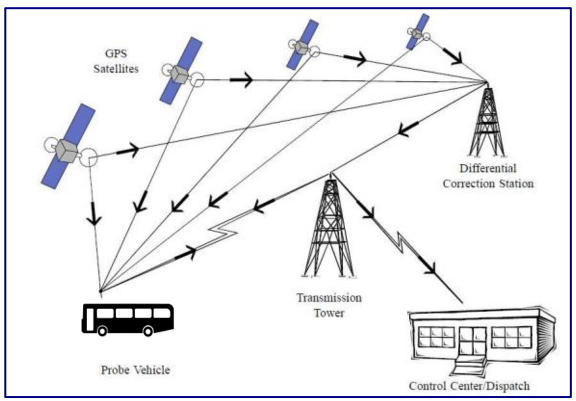
Smart Mobility: SEMINA Project

(Sistemi Evoluti per la Mobilità Intelligente in Network urbani Agili)

Evolved systems for smart mobility in agile urban networks

Aim: Innovative design of an **ICT system** to provide the citizens and the Public Administration of a smart city with useful information about **urban mobility**.

- The urban mobility Information System has been developed and prototyped by the Polytechnic of Bari in collaboration with local SMEs for the Municipality of Bari (Italy)



Methodology: «bus-as-probe», *Data source*: local bus fleet monitored by GPS signals (100 tracked buses/die; 120.000 GPS traces/die)

Advantages: low *cost* of setup and implementation, *automatic* data storage, *scalability* to other probe vehicles.

Smart Mobility: SEMINA Project

(Sistemi Evoluti per la Mobilità Intelligente in Network urbani Agili)

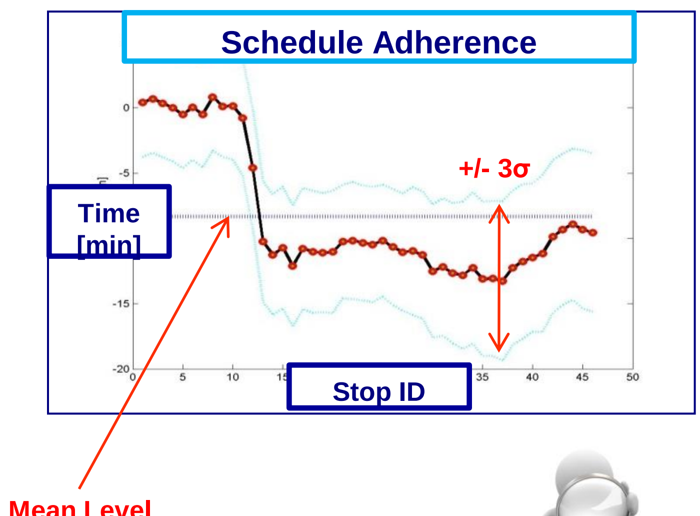
Evolved systems for smart mobility in agile urban networks

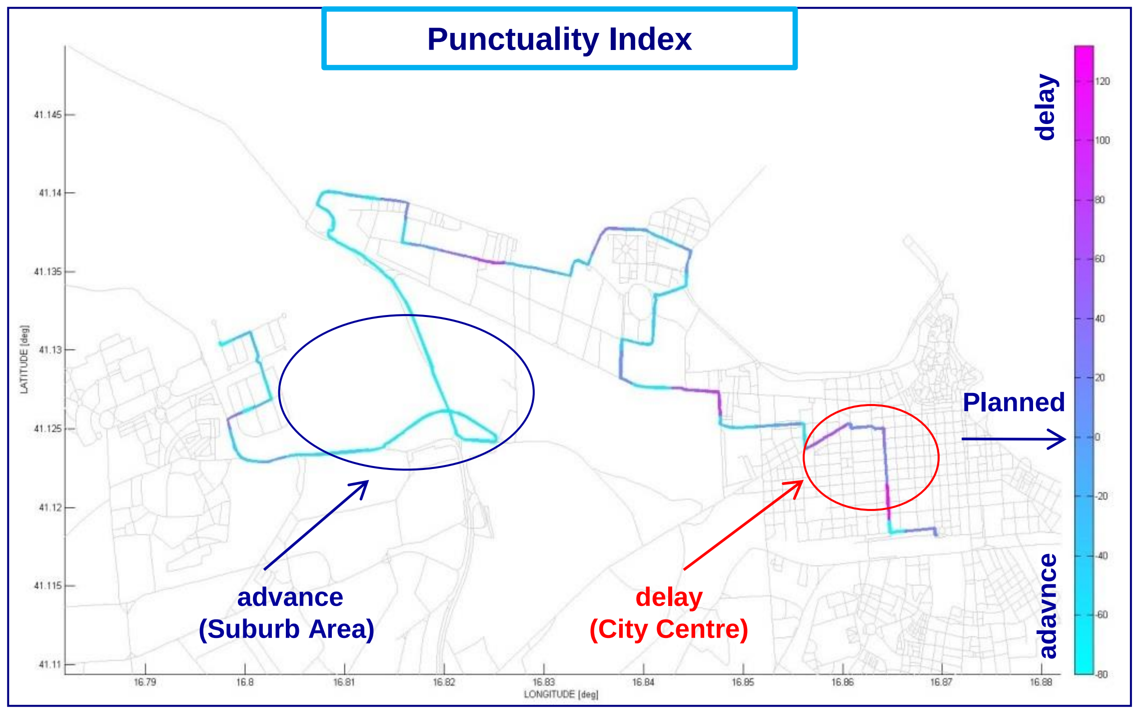
Three levels of analysis:

- Real Time monitoring of urban traffic congestion
- analysis of urban traffic characteristics
- analysis of local public transport bus services

Results - analysis of local public transport bus services:

- Bus line 53, inbounding route, trip scheduled at 08:05 a.m.
- Weekdays statistical analysis in June 2014





Industry 4.0

- Smart manufacturing
- Digital Twin
- Virtual Reality
- Collaborative Robotics

Smart Factory: PICO&PRO Project

(Processi Integrati e COnnessi per l'Evoluzione industriale nella PROduzione)

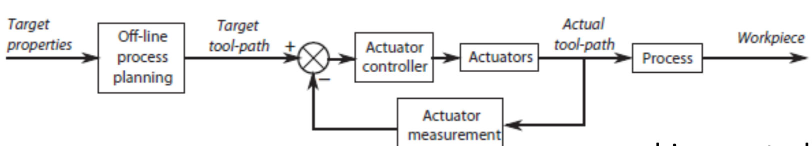
Integrated and Connected Processes for Industrial Evolution in Manufacturing

Aim: Optimization of industrial manufacturing processes in the **automotive sector** using integrated and interconnected systems for:

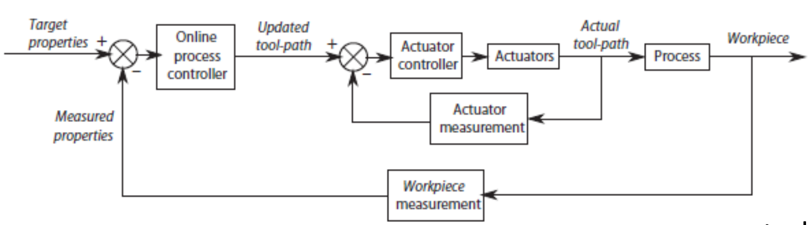
1. Hot / cold sheet metal forming process
2. Assembly / welding process

Methodology: Cyber-Physical System through sensors and actuators

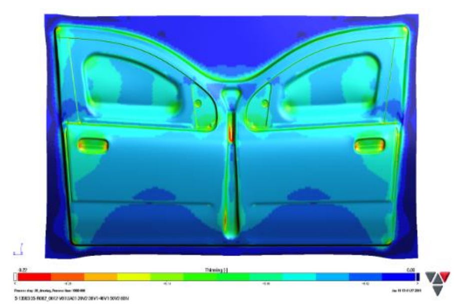
Advantages: self-adaptive control system for the *quality* of the manufactured components; detect *defects* and *correlate* them to the process parameters.



machine control



process control



$$\mathbf{q}_{k+1}(\mathbf{x}) = \mathbf{f}_k(\mathbf{q}_k(\mathbf{x}), \mathbf{u}_k) \quad \mathbf{q}_0(\mathbf{x}) = \mathbf{q}^i(\mathbf{x})$$

metal state

control inputs to the actuators

Smart Factory: PICO&PRO Project

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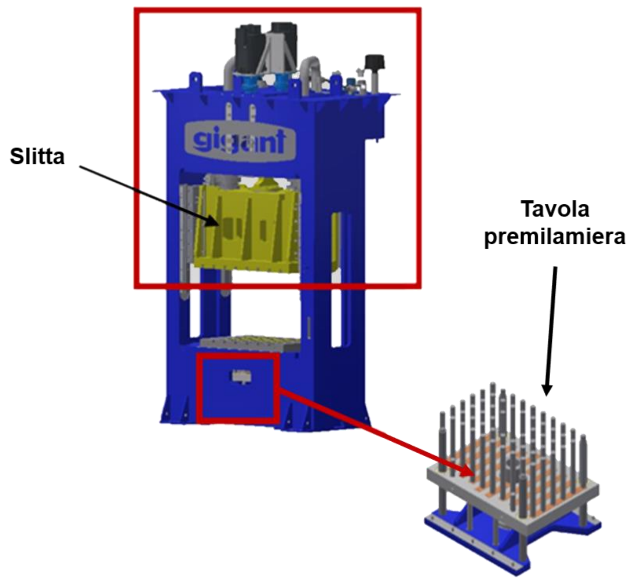
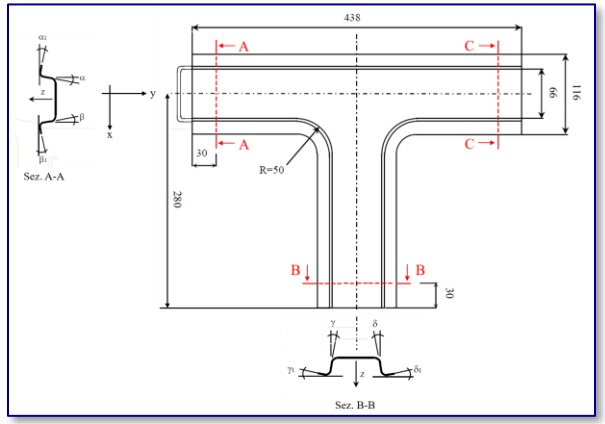
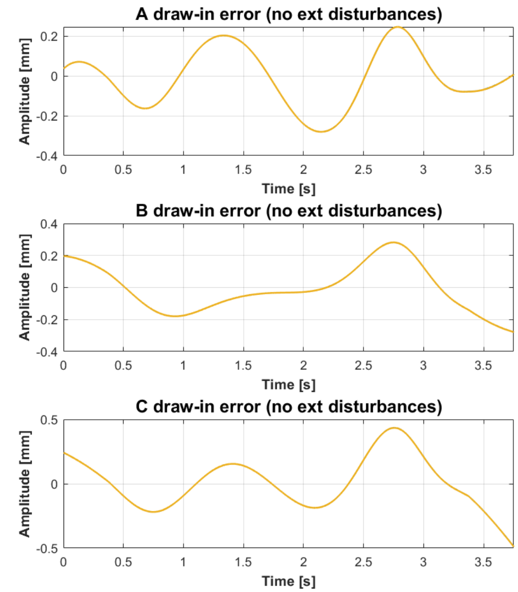
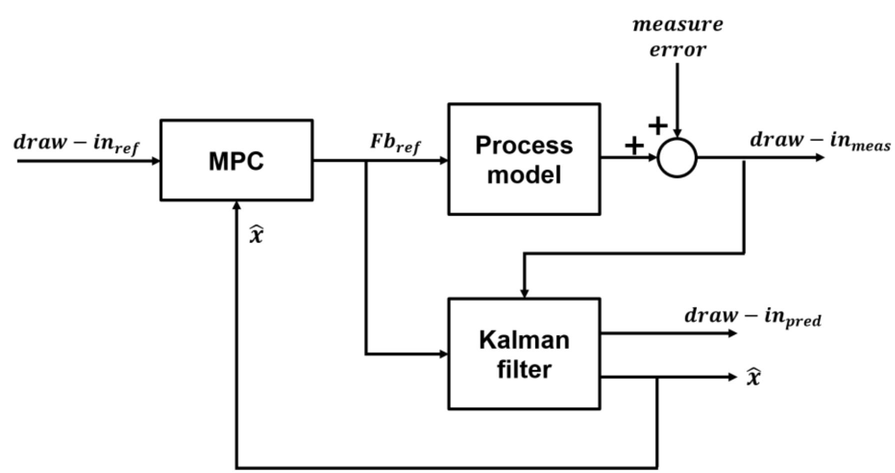
Integrated and Connected Processes for Industrial Evolution in Manufacturing

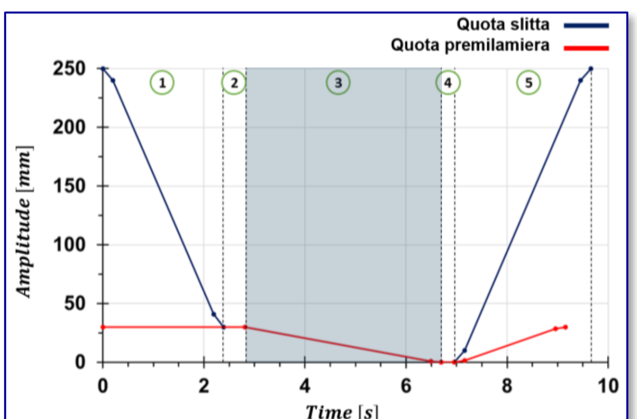
Pressa idraulica





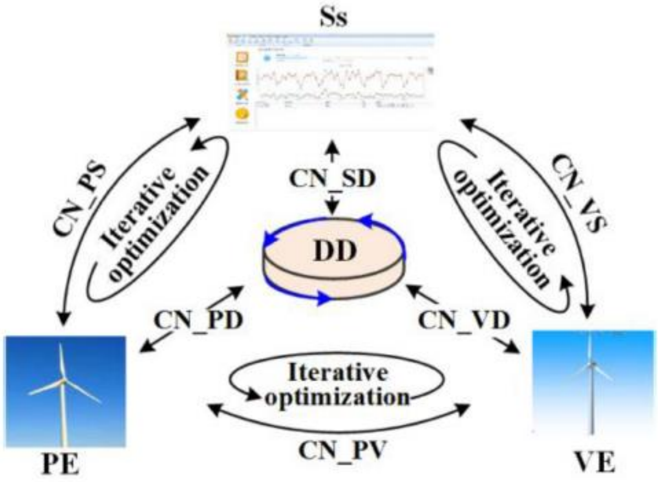






Digital Twin

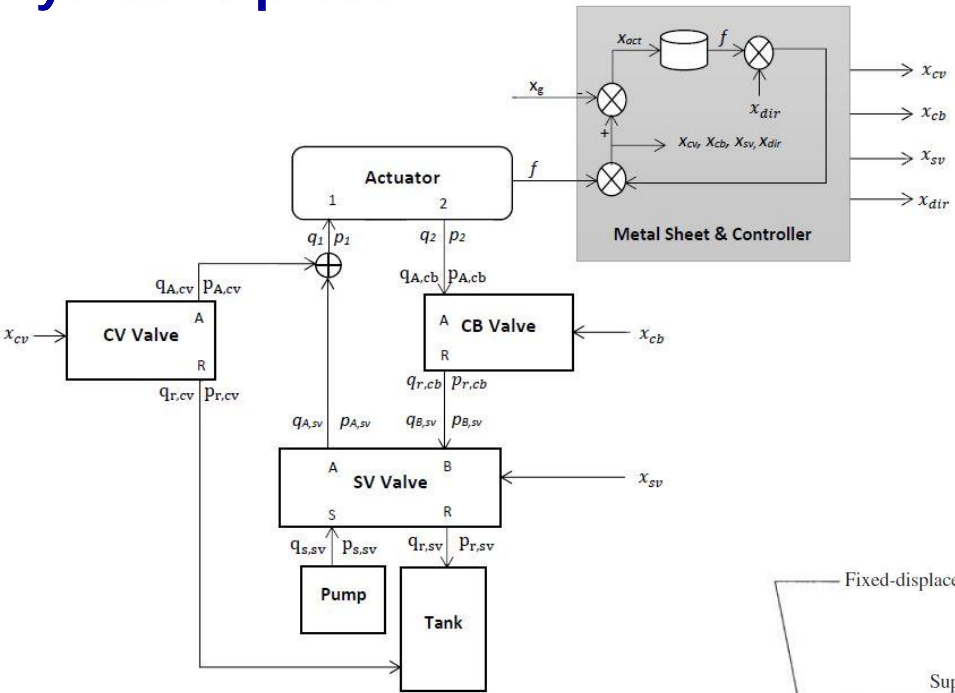
- Cosa è?
  - I DT (“modelli digitali) sono appunto repliche digitali di sistemi fisici. Servono per testare e capire come si comporteranno i sistemi e i prodotti che un’azienda intende realizzare.
  - Si utilizzano a tal scopo, ambienti e simulazioni digitali, virtuali.
- Definizioni:
  - Alcuni ricercatori credono che il DT deve focalizzarsi sulla simulazione
  - **Altri disputano che il DT contiene 3 dimensioni: fisica, virtuale e di comunicazione**
  - **Altri ancora propongono un’architettura a 5 dimensioni:**
    - **PE: entità fisica**
    - **VE: Entità virtuale**
    - **SS: servizi per PE e VE**
    - **DD: dati del DT**
    - **CN: connessioni tra le varie parti**



F. Tao and M. Zhang, “Digital twin shop-floor: A new shop-floor paradigm towards smart manufacturing,” IEEE Access, vol. 5, pp. 20418–20427, 2017

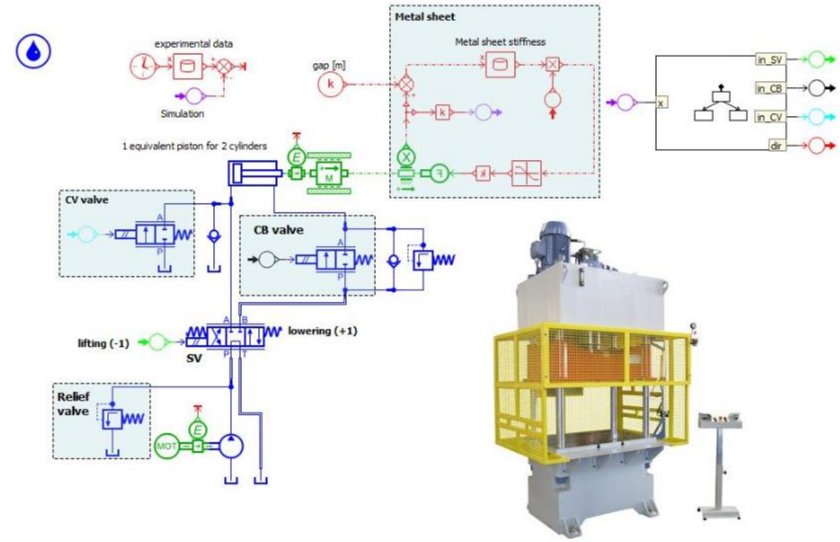
Digital Twin

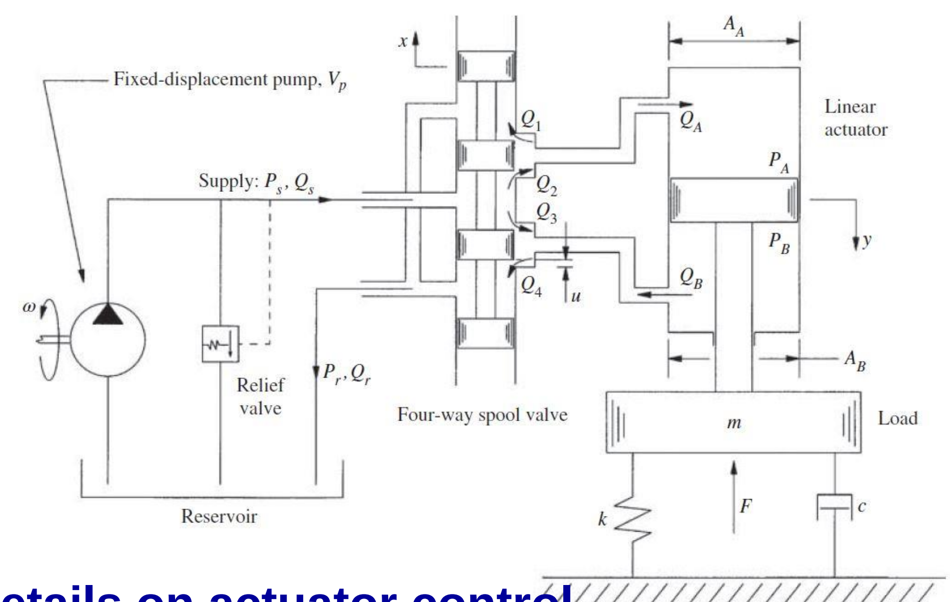
Hydraulic press



System architecture

Amesim Simulation





Details on actuator control

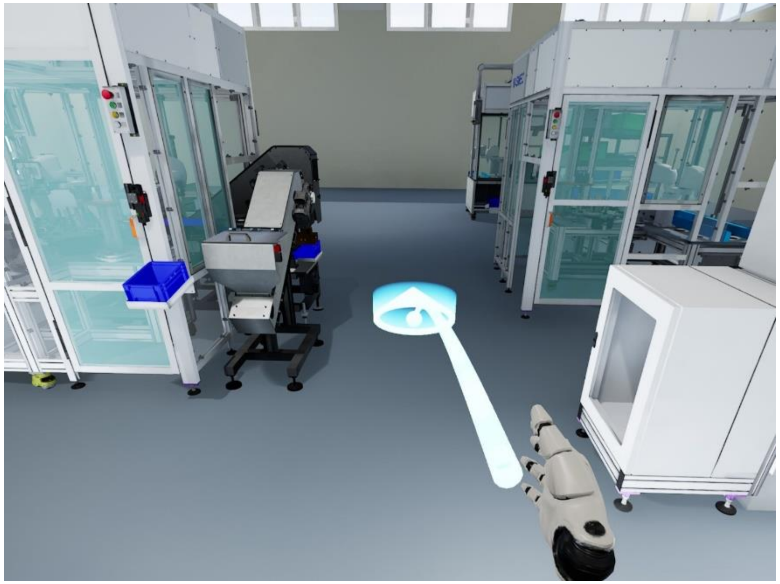
Virtual Reality

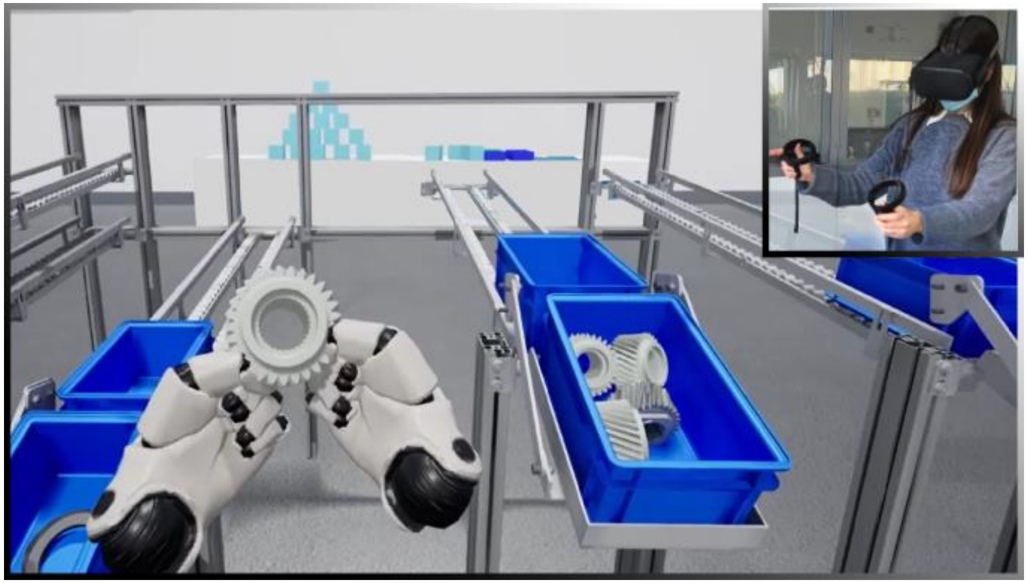
- Virtual reality (VR) is a simulated experience that can be similar to or completely different from the real world. Applications of virtual reality include entertainment (e.g. video games), education (e.g. medical or military training) and business (e.g. virtual meetings). Other distinct types of VR-style technology include augmented reality and mixed reality, sometimes referred to as extended reality

- Throughout the whole product development process, VR is emerging as a powerful tool to decrease design and production costs, while reducing the time needed between product conception and production.

Virtual Reality

- Using Virtual Reality for the Optimal Design of Manufacturing Systems
  – the Case of an Electric Axles Production Line

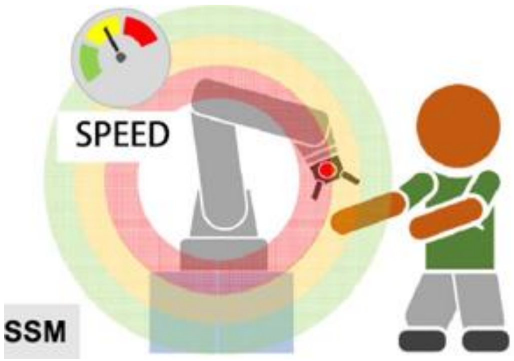




MASMEC

Collaborative Robotics

In contrast to robots that predominantly work independently from humans and often reside in a cage, a **cobot**, or **collaborative robot**, is a robot that co-exists in the same environment together with humans, without renouncing to safety or efficiency



Research on Collaborative Robotics

Advantages:

- Improved ergonomics and employee wellbeing
- Increased profitability and productivity
- Highest quality
- Optimal flexibility
- Pinpoint accuracy
- Space-saving
- Reduced downtime of the system
- Suitable for Small-Scale and Mid-Scale Production

Aims:

- Cobots focus on **repetitive tasks** to help workers concentrate more on tasks that require problem-solving skills
- Cobots are appropriate for **complex** and **dangerous applications**

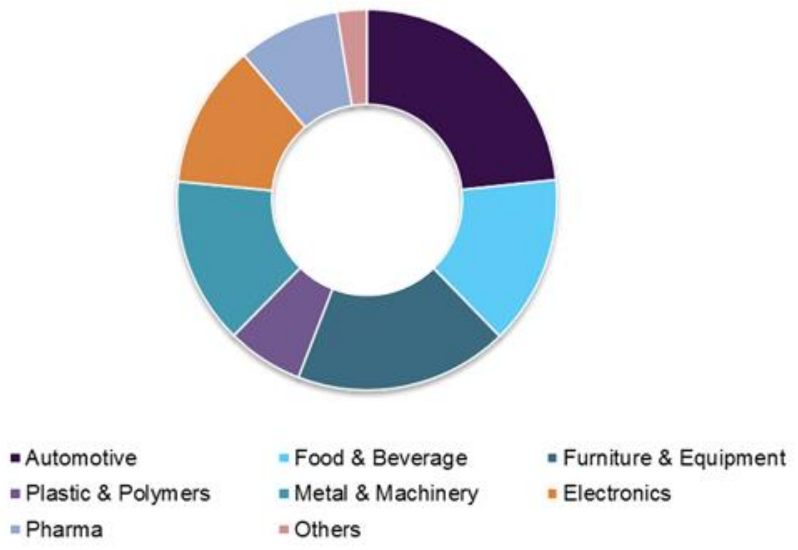
Research on Collaborative Robotics

Applications:

They can be divided into **assembly**, **human assistance** (when the cobot acts as an ergonomic support for the operator, e.g., pick and place, packing, palletizing, material handling, quality inspection, based on vision systems), and lastly, **machine tending**

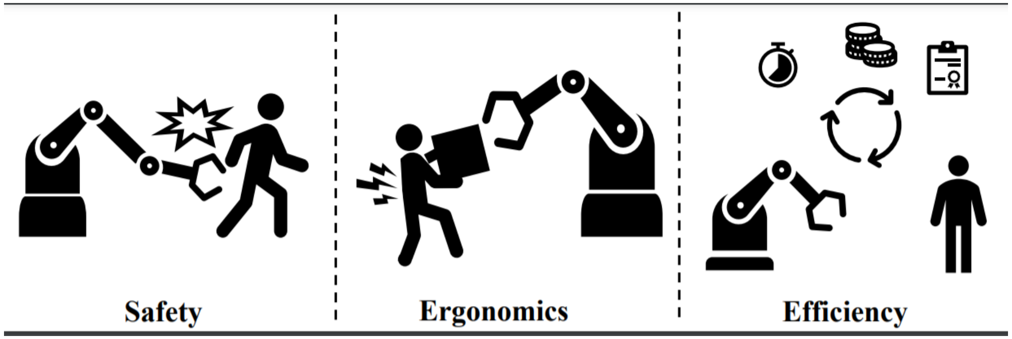
Sectors:

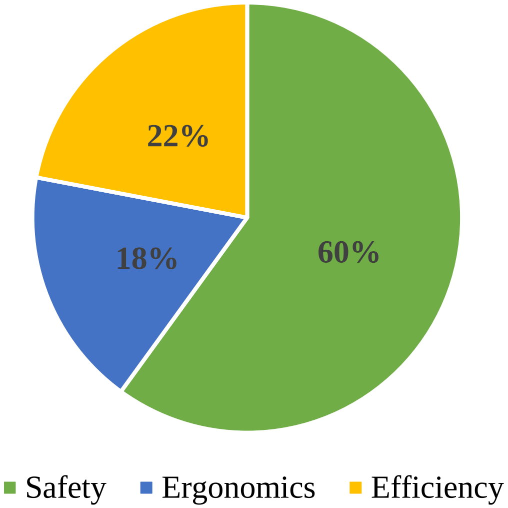
- Automotive
- Electronics
- Agriculture
- Health-care and pharmaceutical
- Food processing
- Logistics and warehousing
- Metalwork



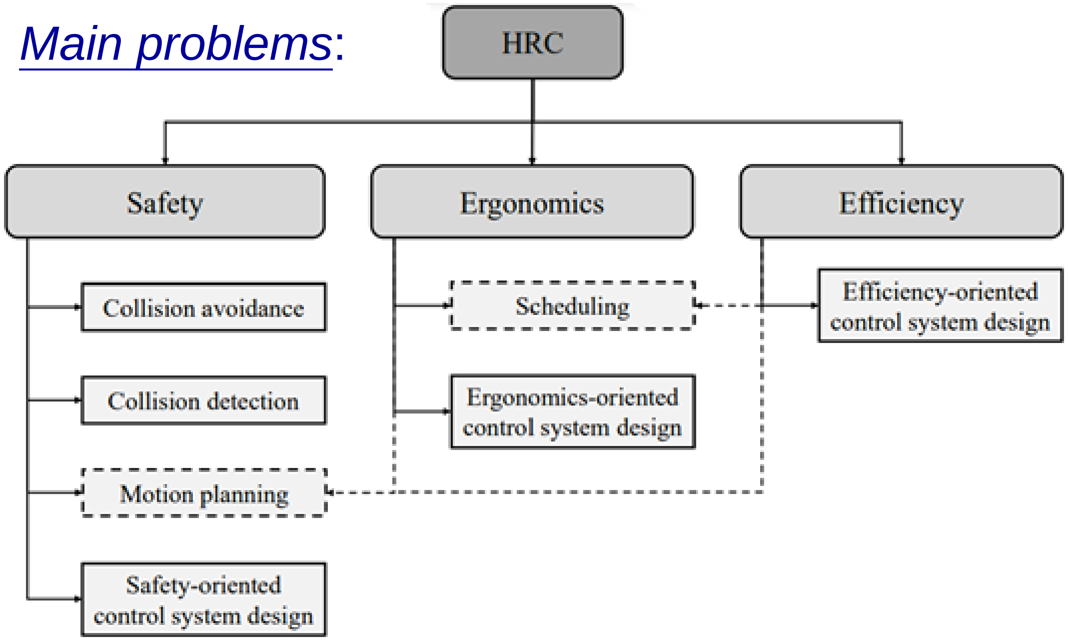
Research on Collaborative Robotics

Three main targets identified in the literature:

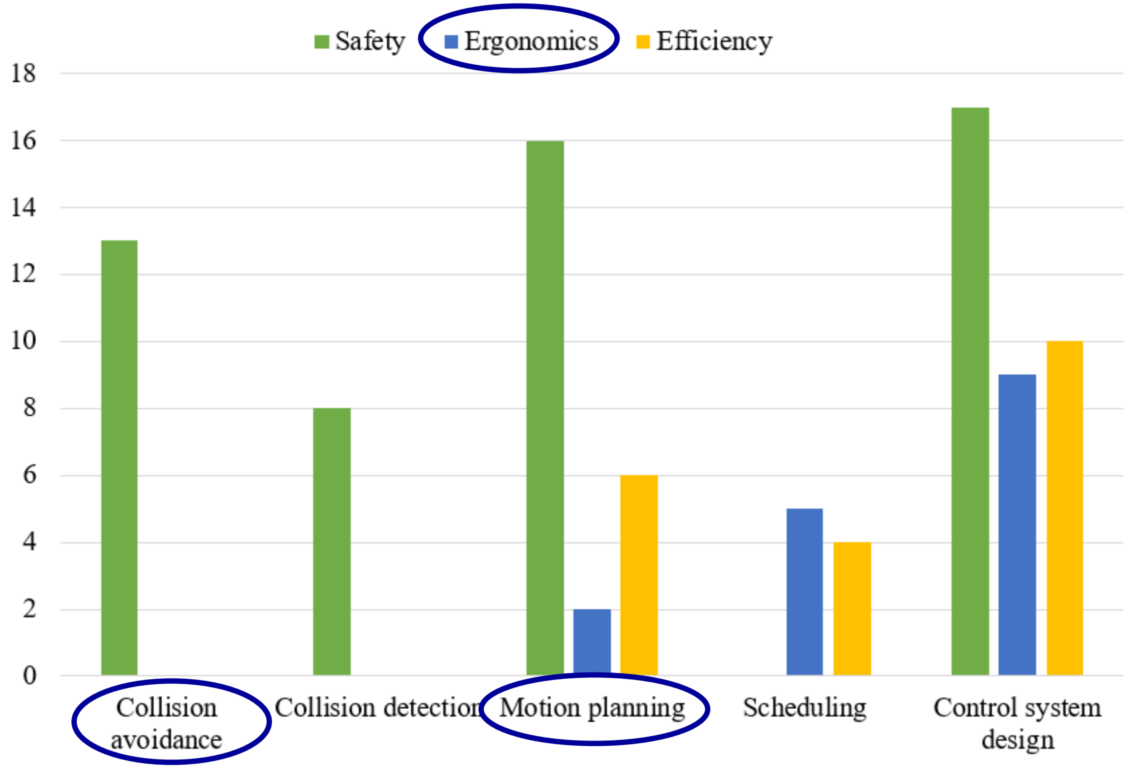




Main problems:



Research on Collaborative Robotics

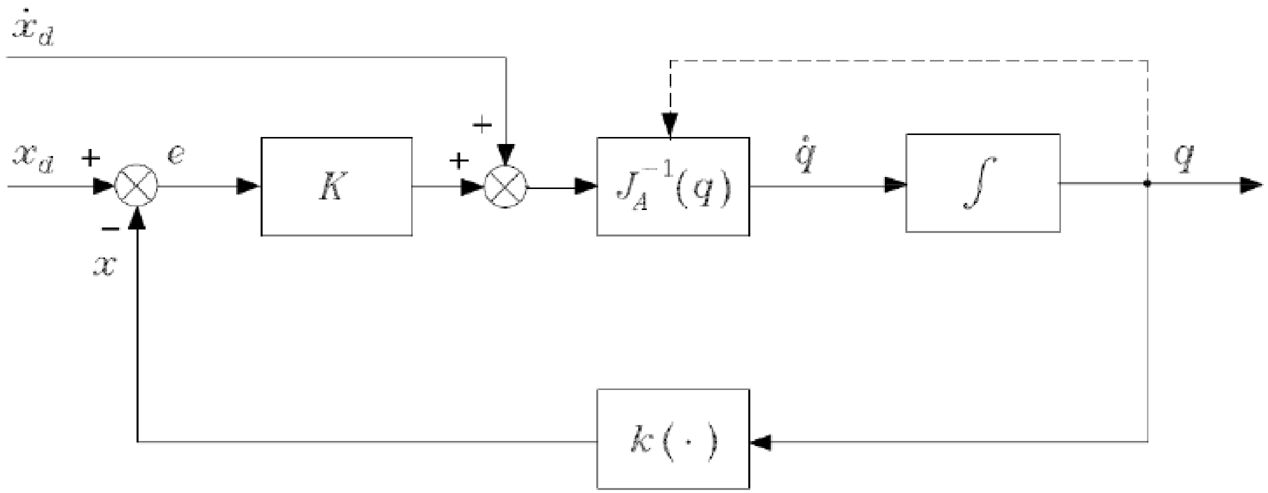


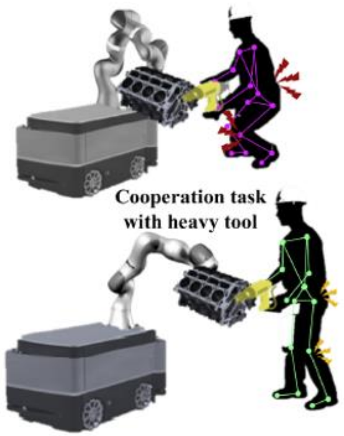
Number of papers related to the analyzed control problems for each HRC target

Current research focus:

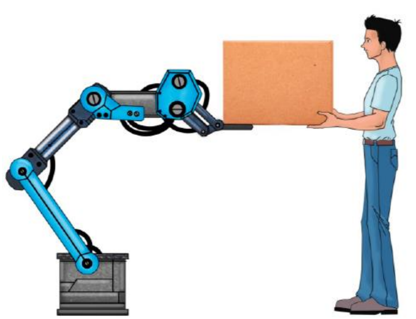
- **Trajectory planning**
- **Collision avoidance**
- **Optimization of the operator's posture (RULA assessment tool)**

Research on Collaborative Robotics





Trajectory planning and collision avoidance (MATLAB / SIMULINK)



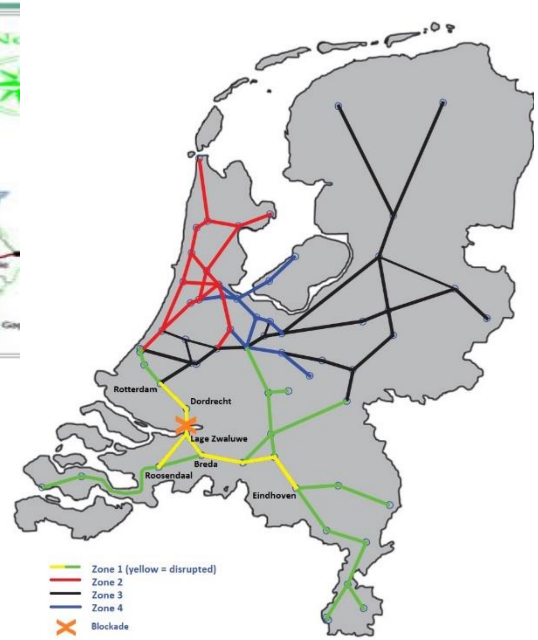
Optimization of the operator's posture (CATIA)

Tranport and Logistics

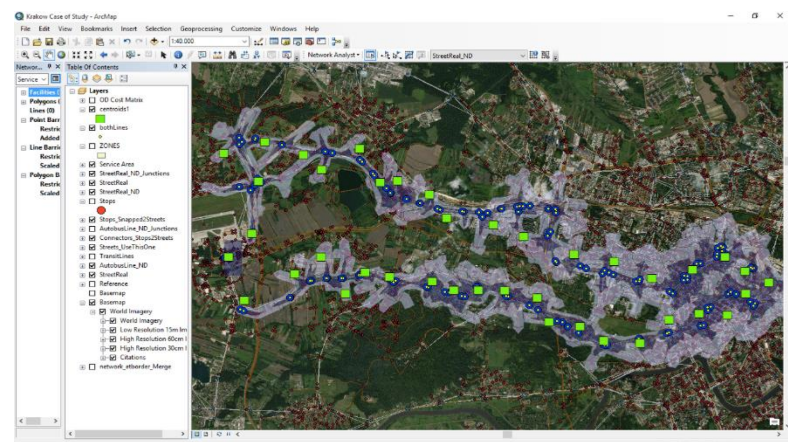
- **Passengers transport**
- **Freight transport**
- **Logistics 4.0**

Research on Transport Systems

- PASSENGERS TRANSPORTATION
  - *Regional railways* (offline scheduling + real-time delay management)
  - *National railways* (real-time disruption management)
  - *Public bus transport* (Dynamic accessibility assessment)



[The main Dutch railway network]



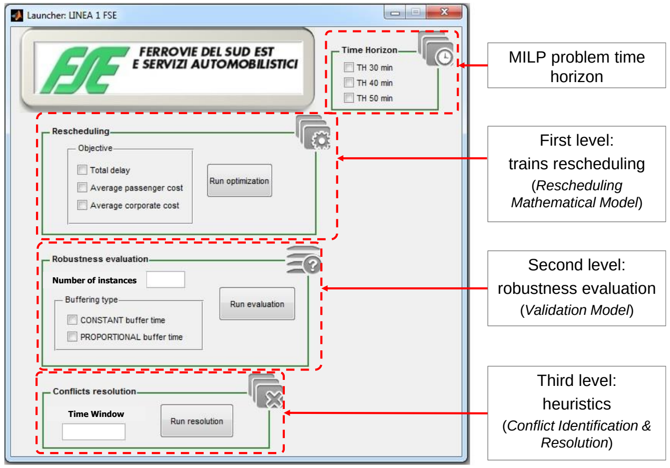
[Cracow bus transportation lines extract]

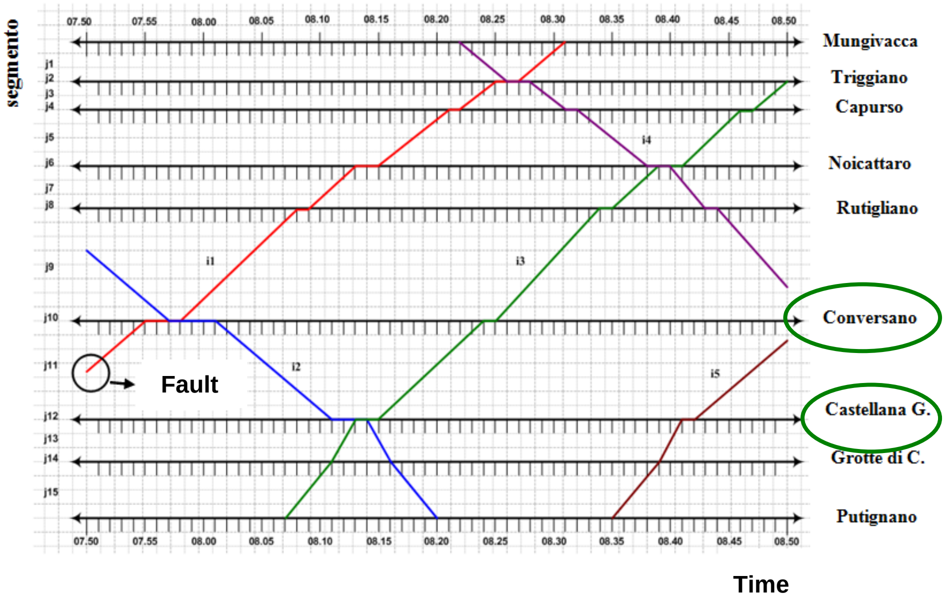
Railway passengers transportation

Aim: **offline** scheduling of the timetable + **real-time** management of disturbances.

Methodology: PES, re-scheduling (Constraints: railway constraints + robustness).

Advantages: min *delays* + *user-friendly* GUI.





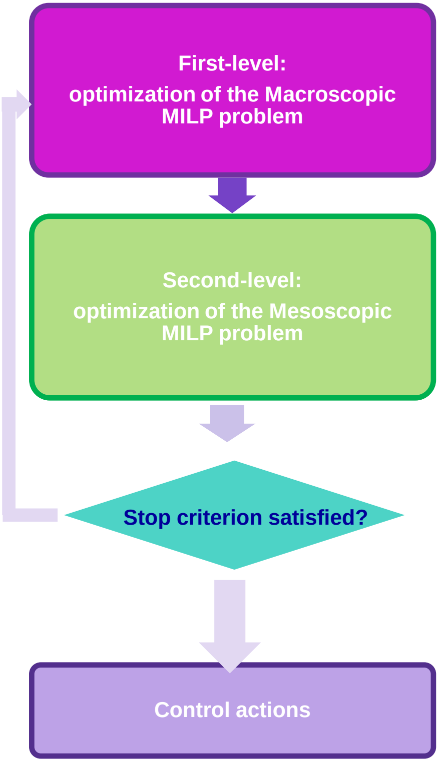
Railway passengers transportation

Aim: **real-time** rescheduling of railway traffic in case of disruption in large-scale networks.

Methodology: MILP macroscopic mesoscopic model, bi-level rescheduling algorithm, Model Predictive Control.

Advantages: min (*delays, cancellations, shuntings*)+ *management of stations activities*.

[The main Dutch railway network]

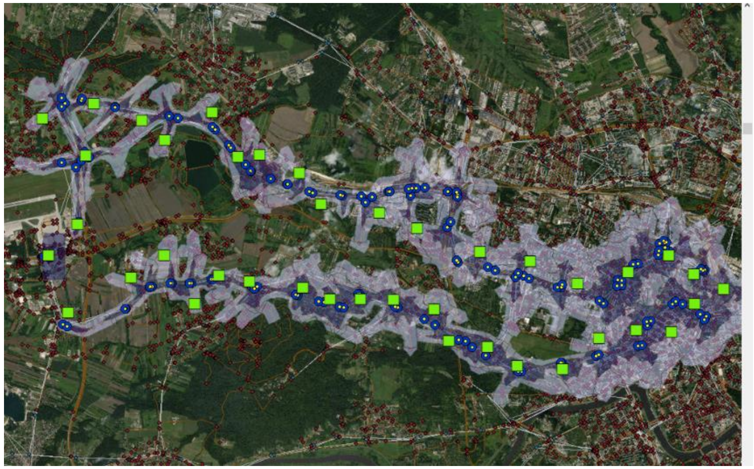


Public Bus passengers transportation

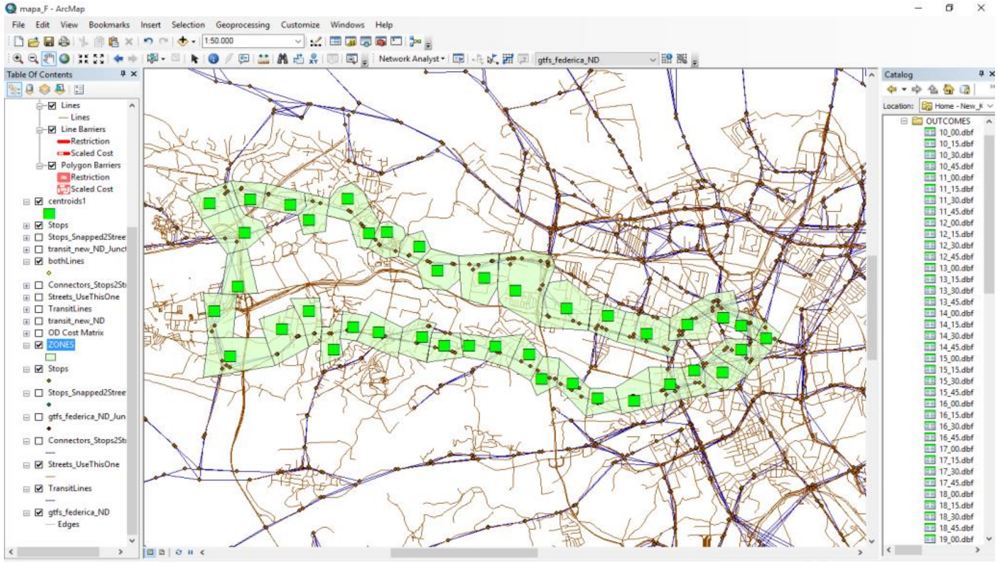
<u>Aim</u>: **Dynamic accessibility assessment**.

<u>Methodology</u>: real GTFS data evaluation and use of ArchGIS program.

<u>Advantages</u>: support to transport management for the improvement of the transport accessibility.



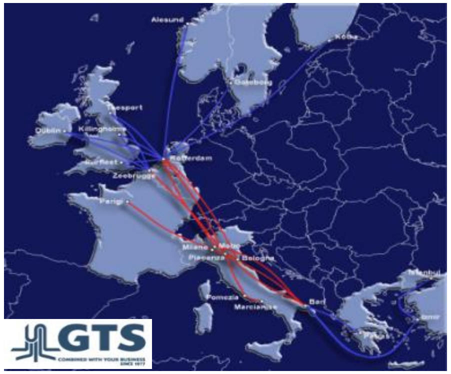
[Cracow bus service extract]



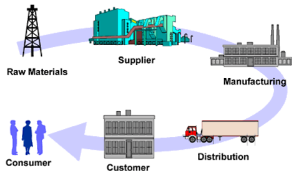
[ArchGIS for the centroids identification]

Research on Transport Systems

- FREIGHT TRANSPORTATION
  - *Logistics* (internal/external)
  - *Intermodal rail-road terminals*
    - detection of *criticalities*
    - *road paths optimization*
    - *yard positioning* of containers
    - *train load planning*
    - *waste collection and transportation* (special and hazardous waste)
    - *multimodal terminals*



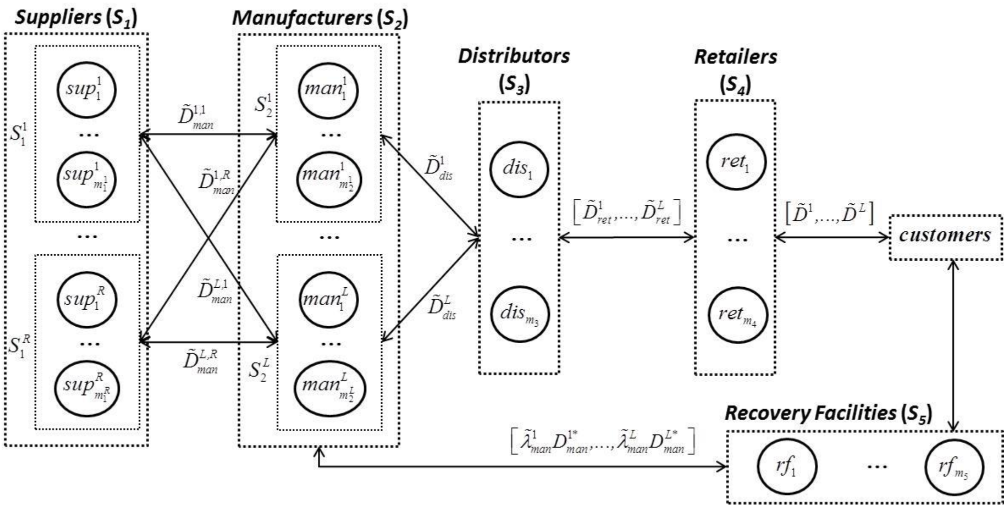
Freight Transport: External logistics

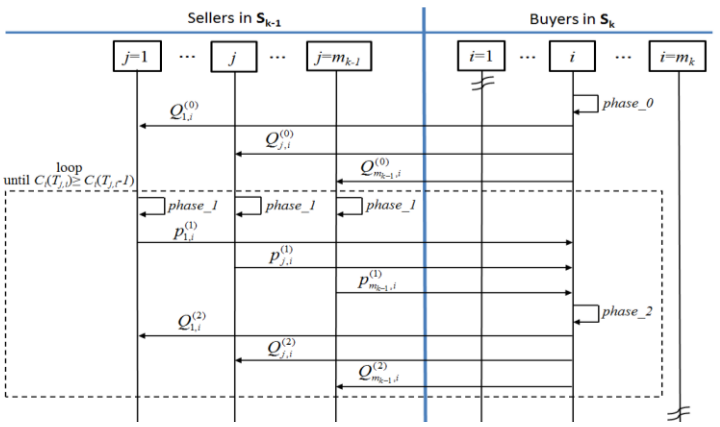


Aim: **strategic design** of an agile Supply Chain Network (SCN) multi-buyer multi-seller under multi-objective and uncertain parameters, **performance evaluation**, **resource management**.

Methodology: cross-efficiency fuzzy/stochastic DEA + fuzzy bargaining game.

Advantages: *flexible* and *efficient* SCN + *cooperation* and *competitiveness* among stakeholders + *time* and *cost* reduction + what-if *analysis*





Freight Transport: Road Paths

Aim: **matching** of delivery and pick-up requests (first/last miles).

Methodology: CVRP(TW) + FFM. (Constraints: max 2 clients per visit; discharge before loading).

Advantages: combination of load/unload activities, *savings* (times, costs, resources).

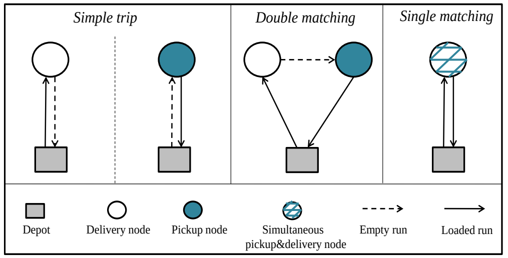
Path	Match	Delivery	Pick Up	Km	t_k [min]
Routes for customers' ITUs (run time 21.04 sec)					
p_1	double	Putignano	Brindisi	224	344
p_2	double	Gravina	Massafra	179	299
p_3	double	Melfi	M. Savoia	208	328
p_4	double	Foggia	M. Savoia	229	349
p_5	double	Valenzano	Monopoli	92	212
p_6	simple trip	Modugno	/	12	72
p_7	simple trip	Valenzano	/	18	78
p_8	double	Buccino	Statte	359	479
Routes for owned 45' ITUs (run time 41.74 sec)					
p_9	double	Trani	Buccino	284	404
p_{10}	double	Fasano	Cavallino	297	417
p_{11}	no match	/	Statte	142	202
p_{12}	single	Andria	Andria	92	212
Routes for owned 20' ITUs (run time 22.06 sec)					
p_{13}	double	Fasano	Cavallino	297	417
p_{14}	no match	/	Putignano	82	142
p_{15}	single	Andria	Andria	92	212
p_{16}	double	Policoro	Buccino	356	476

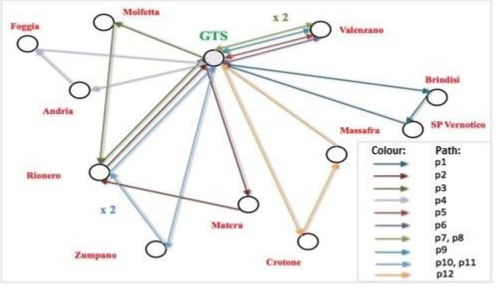
Scheduling for with customers' ITUs (run time 0.053 sec)

		path								T_v [min]	T_{over} [min]
		p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8		
vehicles	v_1		x				x	x		449	0
	v_2				x					349	0
	v_3	x								344	0
	v_4			x						328	0
	v_5					x				212	0
	v_6								x	479	0

Scheduling for owned ITUs (run time 0.0517 s)

		path								T_v [min]	T_{over} [min]
		p_9	p_{10}	p_{11}	p_{12}	p_{13}	p_{14}	p_{15}	p_{16}		
vehicles	v'_1			x	x					414	0
	v'_2						x	x		354	0
	v'_3					x				417	0
	v'_4		x							417	0
	v'_5	x								404	0
	v'_6								x	476	0



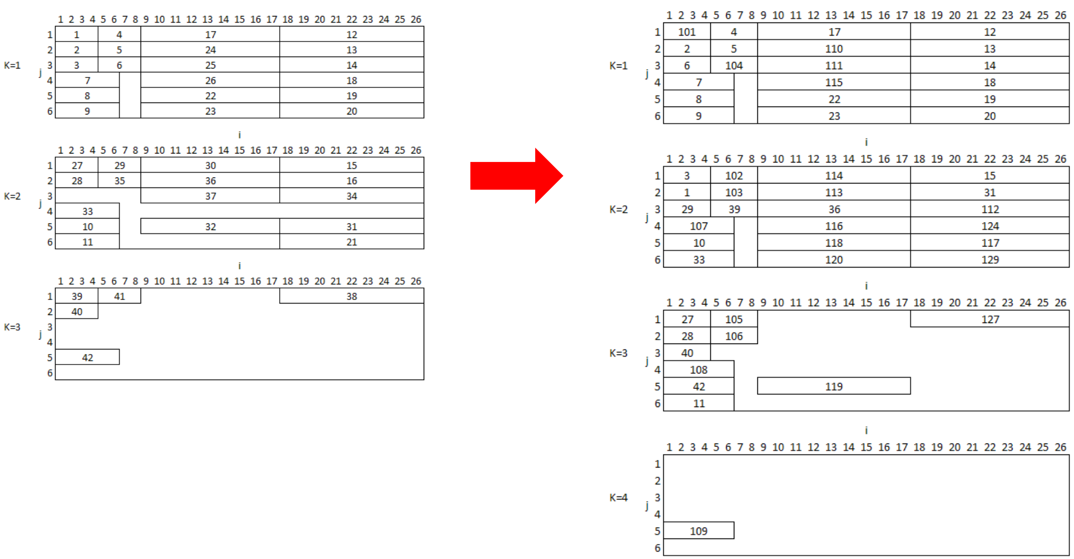


Freight Transport: Yard Positioning

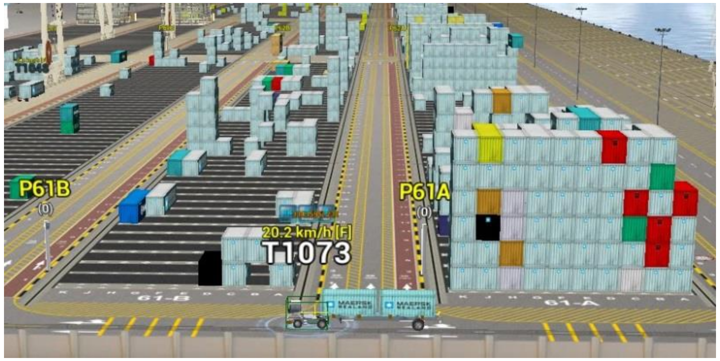
Aim: maximize the yard fullfillment.

Methodology: Knapsack problem (Constraints: capacity, stackability, economic and commercial value, stringency, customers importance).

Advantages: *profit* increase, reduction of removals, cost, and time, informatization, better use of resources, departures/arrivals management.



GTS

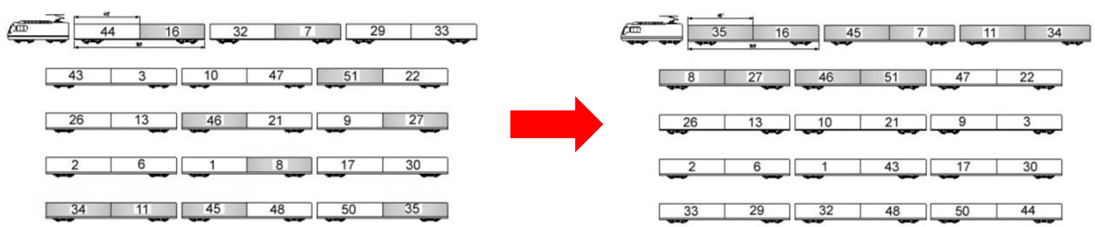


Railway freight transport optimization

Aim: global optimization.

Methodology: MILP + heuristics (Constraints: dimension; weight; priorities; customers importance; empty ITUs + railway constraints + robustness + reshuffle for the train's head/tail positioning of prosecuting ITUs).

Advantages: max *profit*, handling *overbooking* + management of *intermediate stops* and *contingencies* (discarded ITU or new urgency).

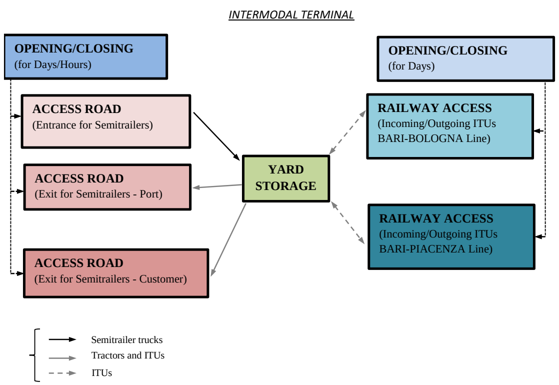


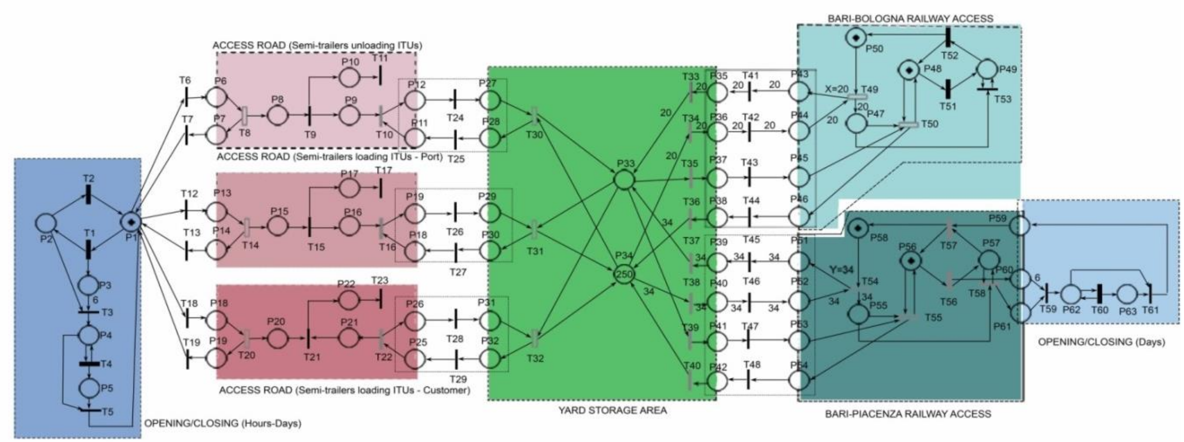
Freight Transport: Multimodal terminals

Aim: **strategic management** of combined freight transport terminals, **performance evaluation,** and **resource management.** Also useful for process re-engineering.

Methodology: discrete event simulation (Petri Nets: Timed Stochastic + First-Order Hybrid).

Advantages: *standardized* and *modular* modeling + *dynamic analysis* + *simulation* and *what-if analysis* + application of *control policies*.



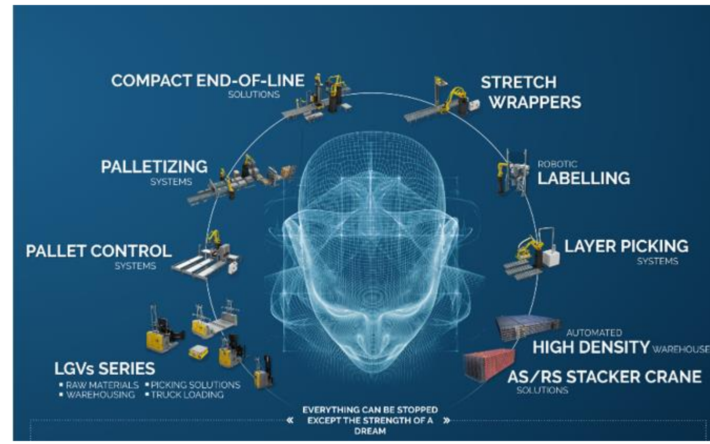


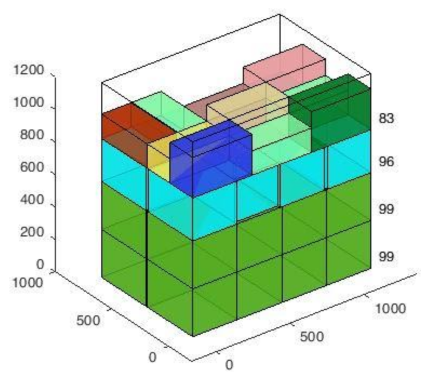
Internal logistics: Bin packing

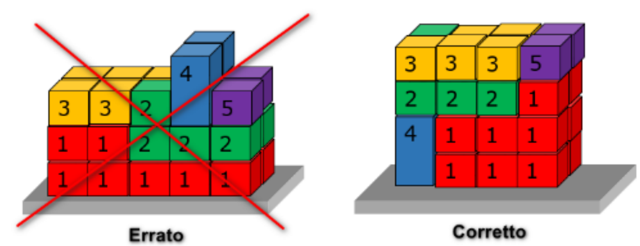
Aims:

- determine the optimal configuration (optimization of volume and space) of pallets, choosing the optimal arrangement of items on a pallet according to soft and hard rules, constraints, and priorities

Bin-packing problem: items of different volumes must be packed into a finite number of bins or containers each of a fixed given volume in a way that minimizes the number of bins used.



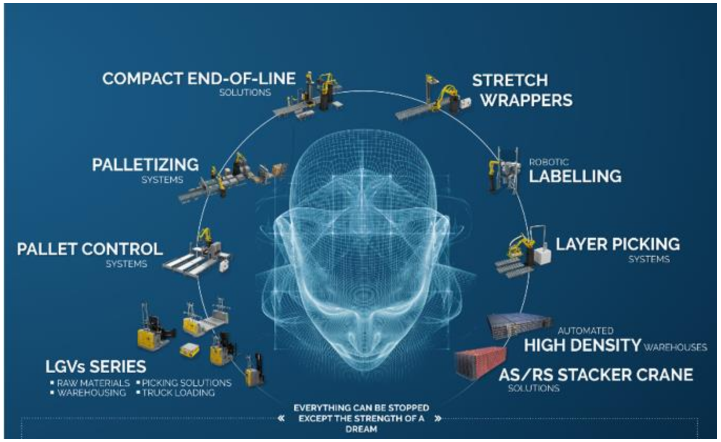




Internal logistics:Smart picking

Aims:

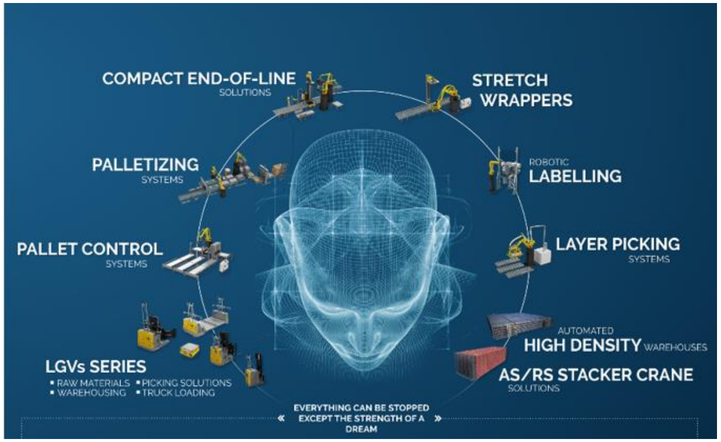
- Optimize of the picking routes and strategies, through a decision support tool that allows to obtain the optimal distribution (also dynamic) of different items within a dedicated warehouse



External logistics: Container loading problem

Aims:

- determine the optimal configuration (optimization of volume and space) of bins, choosing the optimal arrangement of pallets inside the transport unit taking into account some hard rule such as the unloading order, the stability and the balancing



External logistics: Transport Management System

Aims:

- Determin the best routing plan, given a set of orders and clients during a workday.
  - Choice of the best transport unit among a given fleet
  - Choice of the fastest and/or the most economic route
- Dynamic and periodical recalculation of the routes according to the traffic conditions