Towards an emergent transport system of systems for Europe

Brussels, 21 October 2009

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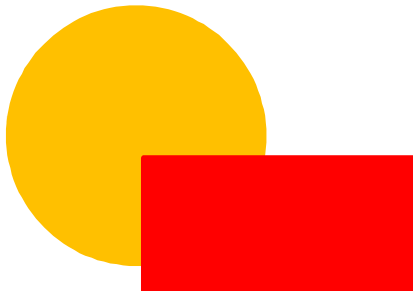
Emergence means the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems.



A common vision of strategic intent and shared value systems are needed to cope with climate change, security issues and other important aspects of our society.

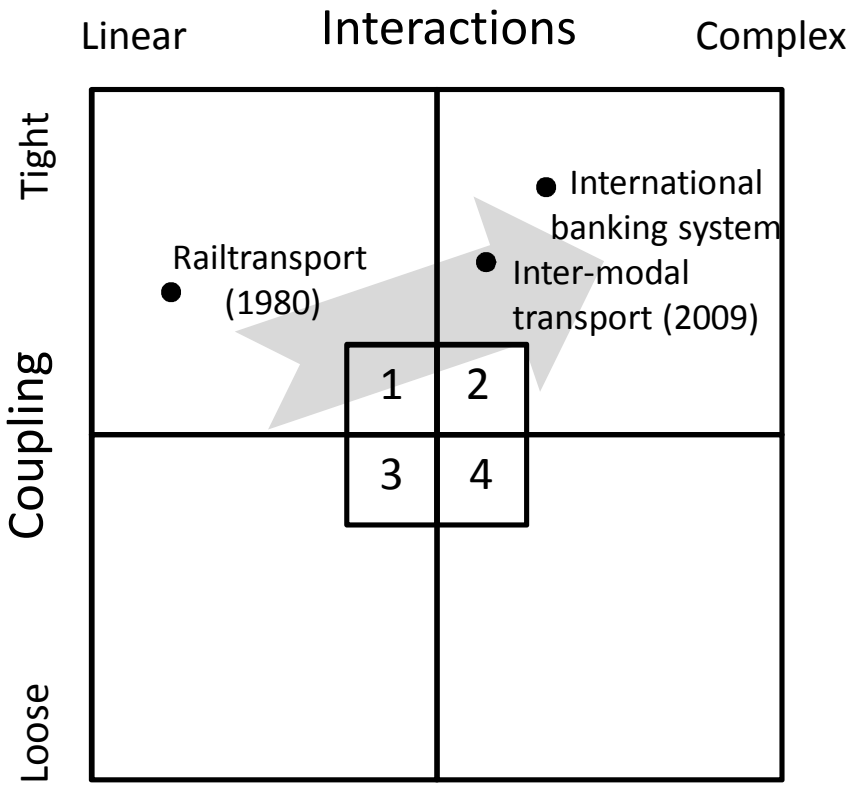
A conceptual leadership can create a strong dynamic force in our society as it generates ‘rally around the flag’ effects and as it gives clear directions to policymakers, public authorities, the industry and the general public.

Conceptual leadership will leverage legislative and other forms of control and will generate innovations and speed up the deployment of new technologies and good practices in the marketplace.

Transport and logistics systems are strongly connected and complex adaptive systems of many individuals, firms, and authorities acting in parallel, constantly acting and reacting to what the other parties are doing.

Coherent behavior in the system arise from competition and cooperation among the different actors. The overall behavior of the system is difficult to predict as it is the result of a huge number of decisions made every moment by many actors.

Our transport systems become more and more complex and tightly coupled systems



Perrow's Authority Rules

Complex but loosely coupled systems are best **decentralized** (4)

Linear and tightly coupled systems are best **centralized** (1)

Linear and loosely coupled systems can be **either** (3)

Complex and tightly coupled systems can be **neither** (2)

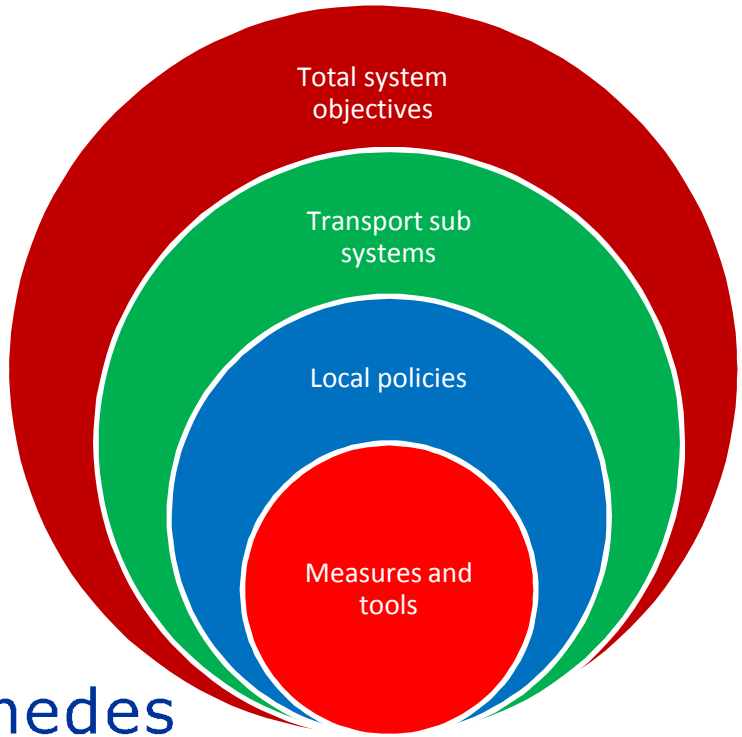
Perrow, Charles (1984). Normal Accidents: Living With High Risk Technologies. (Revised edition, 1999). Princeton, NJ: Princeton University Press.

Many of our transport policies, measures and tools, including “Intelligent” Transport Systems, fail because of a limited focus, a lack of common vision and co-ordinated action and our inability to cope with growing complexity

"A better exploitation of the network's capacity and of the relative strengths of each mode could contribute significantly to reducing congestion, emissions, pollution and accidents. This, however, requires the optimisation and operation of the network as a single entity, whereas currently modal networks are largely separated and even within modes there is a lack of integration between countries."

European Commission, A sustainable future for transport — Towards an integrated, technology-led and user-friendly system, 2009.

A holistic view, combining linear and nonlinear techniques, is needed to understand the behaviour of the total transport system and to develop and evaluate effective and efficient transport policies, measures and tools



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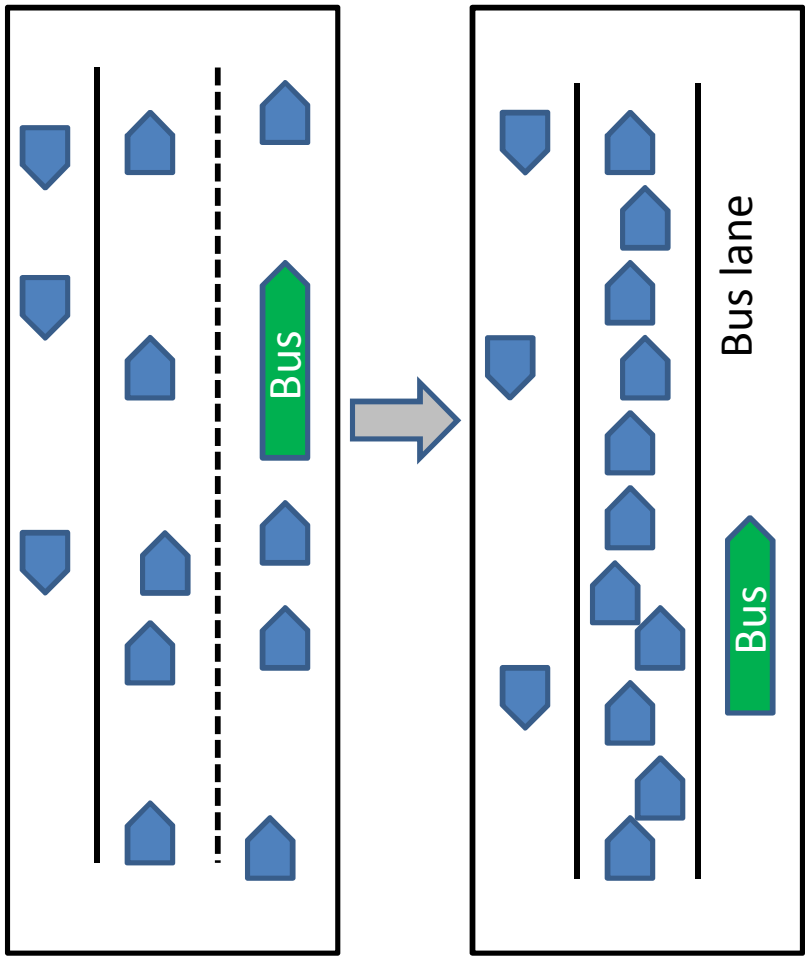
Solutions commercialised by a company versus total system's objectives

Common use of assets will reduce cost and emissions per unit, but …

As the supplier's objective is to maximize the number of assets it will strongly limit the opportunities for further improvements in the system

E.g. Companies providing business solutions in equipment pooling services (e.g. containers, pallets, trays, ..), versus

A total system approach where companies decide to use a **common pool of assets** with the objective to improve the **availability of assets** for each partner, to **minimize the number of assets** in the system and **to minimize transport and transport costs** (lower 'asset'-kilometres, use of empty capacity).



Carrot and stick approaches do not always result in the desired change as transport users do not act as expected (e.g. limited effect of modal shift policies)

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A blueprint of an emergent transport system of systems

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The need for - and the problem of ICT integration

The optimisation and operation of the transport network as a single entity requires the integration and connection of different Information and Communication Technology systems and sub-systems. (EU Commission, 2009)

ICT components and subsystems need a total system design that avoids the introduction of constraints that may hamper future integration in a larger system.

The need for - and the problem of ICT integration

The integration of data can be done independently in several transport networks and supply chains but would be leveraged through a common vision and strategy on a much higher level.

Central command and control systems lack the ability to cope with large complexity and needs a lot of processing and memory.

System of systems

System of systems are inspired by swarming and the behaviour in ant colonies. It moves away from the traditional model of a rigid chain of command to meet the challenges of complexity and uncertainty. Swarming requires autonomous or semi-autonomous operating agents, with strong synchronization and communications among them.

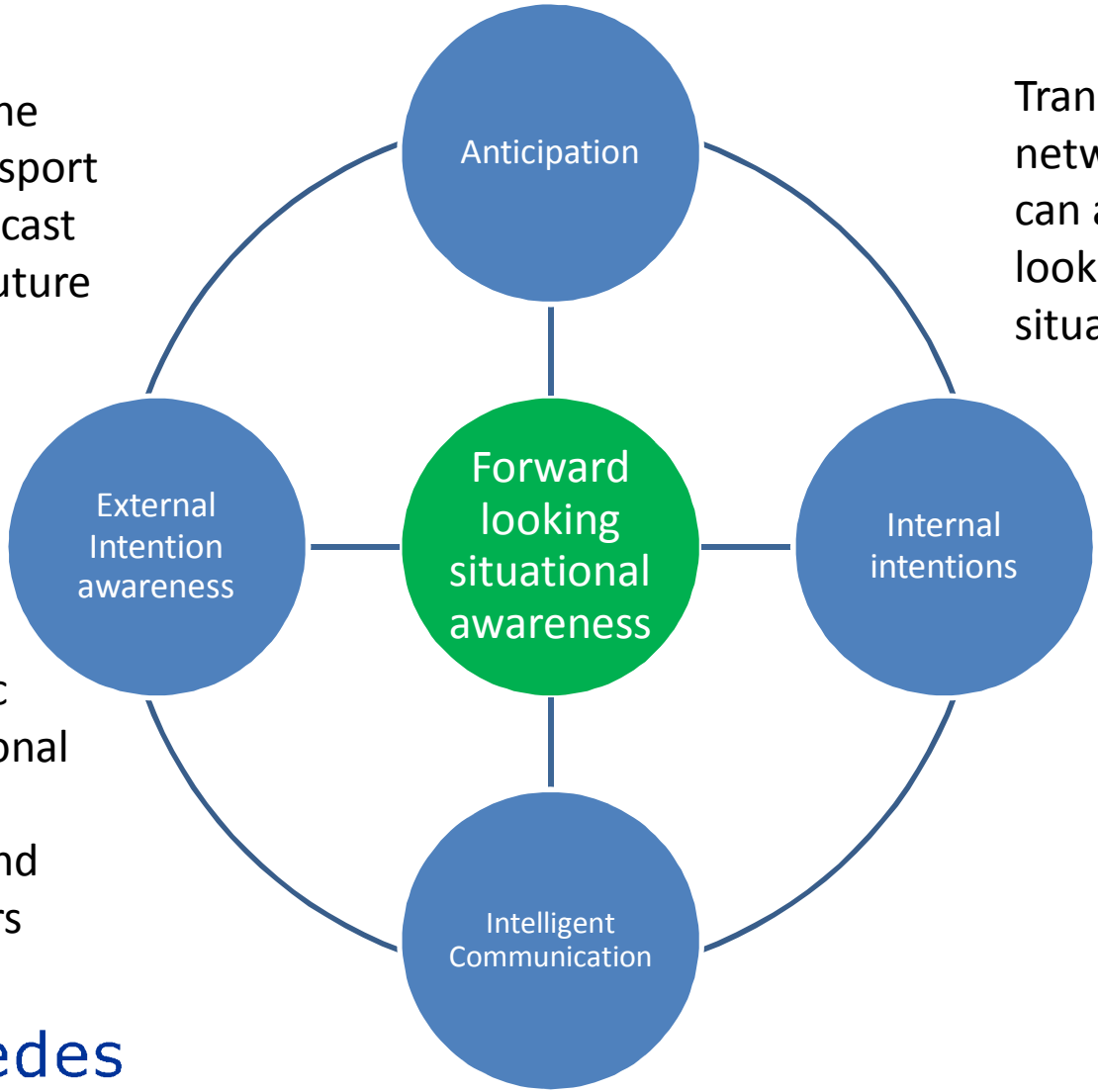
A System of systems is able to perform functions that can not be found in any component system, and these functions are the main System of systems objectives.

Component systems are able to operate when they are not integrated in the System of systems and keep operating independently, at least so some extent, while they are integrated in the System of systems.

A System of systems grows and evolves with time and experience.

Forward looking situational awareness by adding intention awareness of transport users and transport network managers

When we know the intentions of transport users we can forecast and change the future



Transport users and network managers can anticipate forward looking virtual situations

A central dynamic map gives situational information to transport users and network managers

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Combining linear programming with delegate MultiAgent technologies dMAS seems to be the most appropriate ICT architecture for this model as it can cope with the complexity of a transport system and because it limits computational power and memory capacity requirements.

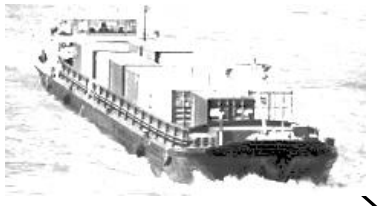
Delegate Multi Agent Systems dMAS is inspired by food foraging in ant colonies. An agent (ant) is a small piece of software that acts for a user or other program and is able to delegate tasks to other agents. A multi-agent system (MAS) is a not centralised controlled system composed of multiple interacting intelligent agents.

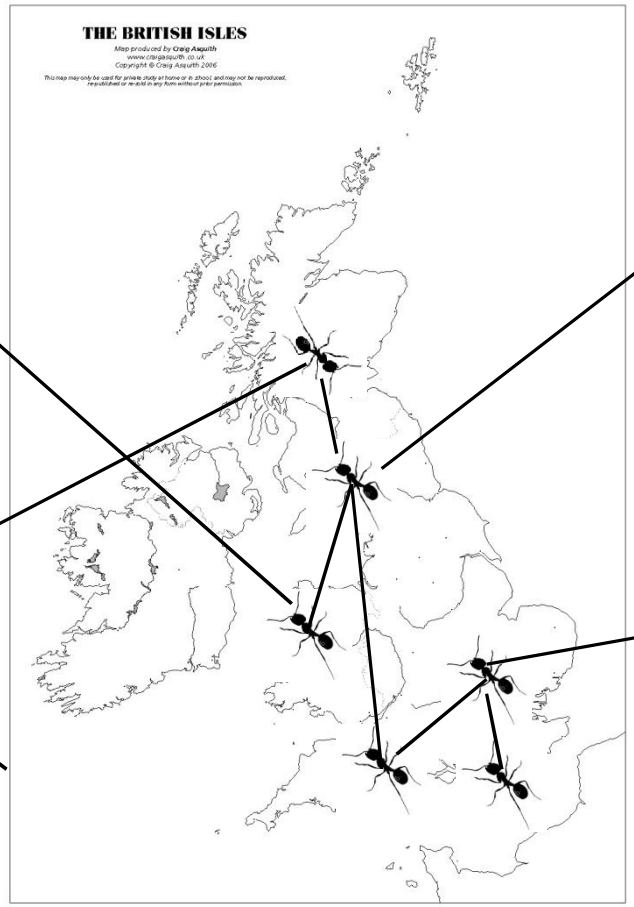
In the **intention D-MAS**, each ant agent virtually executes a chosen tasks (e.g. journey). During this virtual journey, the ant agent reserves the required capacity with the intelligent resources involved. As reservations have to be reconfirmed the effect of changes are known. Failure to reconfirm in time makes a reservation disappear. This permits the system to treat changes and disturbances as business as usual. This software design generates emergent behaviour and foward looking capabilities.

Sources: Danny Weyns, Tom Holvoet and Alexander Helleboogh. Anticipatory Vehicle Routing using Delegate Multi-Agent Systems, Intelligent Transportation Systems Conference, Seattle, 2007

Paul Valckenaers, Bart Saint Germain, Paul Verstraete, Jan Van Belle, Hadeli, Hendrik Van Brussel. Intelligent products: Agere versus Essere, Computers in Industry 60 (2009) 217–228

An intelligent dynamic interactive forward looking map, interconnected with individual transport users and transport network managers represented by intelligent agents (ants) each executing and delegating small tasks.





Data feedback in function of data user requirements

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As with large transport infrastructure, the development and implementation of an emergent system of system is only feasible if initiated by public authorities.

An emergent system of systems will boost the market of all kind of applications and intelligent transport systems and will create an holistic way of thinking and social-economic behaviour.

An intention dMAS System of systems is technological feasible.

The creation of an intention dMAS System of systems is possible in the coming 5 to 7 years and can be fully operational for a large part of the whole European transport system in 30 years time.

It can grows and evolves with time and experience.

- What are we trying to accomplish?
- How is it done now, and with what limitations?
- What is truly new in our approach which will remove current limitations, risks and improve performance?
- How much will performance improve?
- If successful, what difference will it make?
- What are the mid-term and full scale applications required to prove our model?
- Who do we have to involve in the next phases?
- How do we communicate and explain the model to stakeholders?
- How do we handle transition?
- How much will it cost?

International multidisciplinary working group on System of systems design for complex transport systems

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Altimedes is a European consultancy based near Brussels with a strong expertise in the development and implementation of sustainable transport and logistics policies for corporations, public authorities and horizontal and vertical collaborative logistics networks.

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