

# 11<sup>th</sup> SMMSO 2017

## **Intelligent evaluation of suppliers' sustainability performance using multi-agent systems in distributed supply chains**

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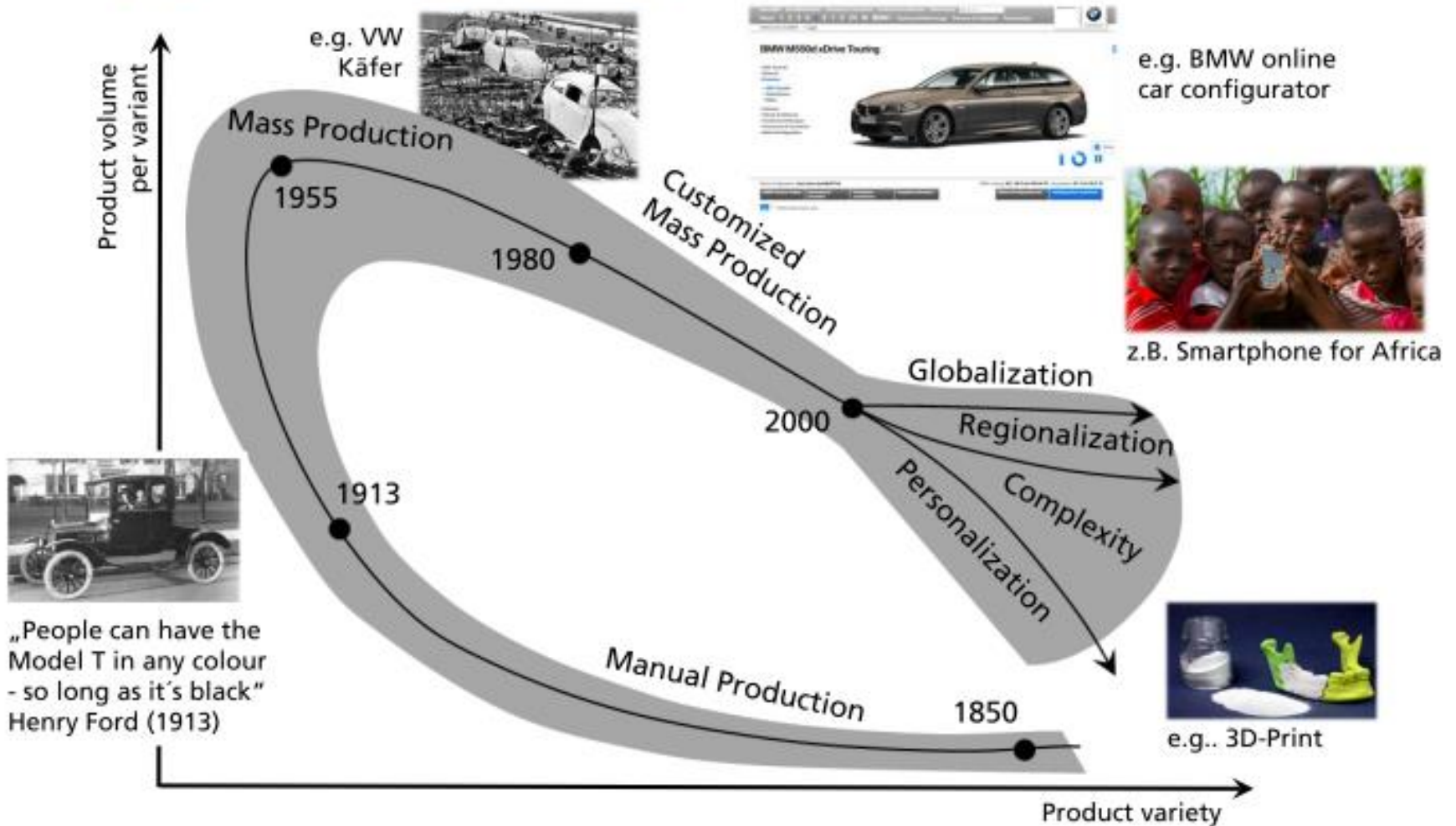


# Outline of Presentation

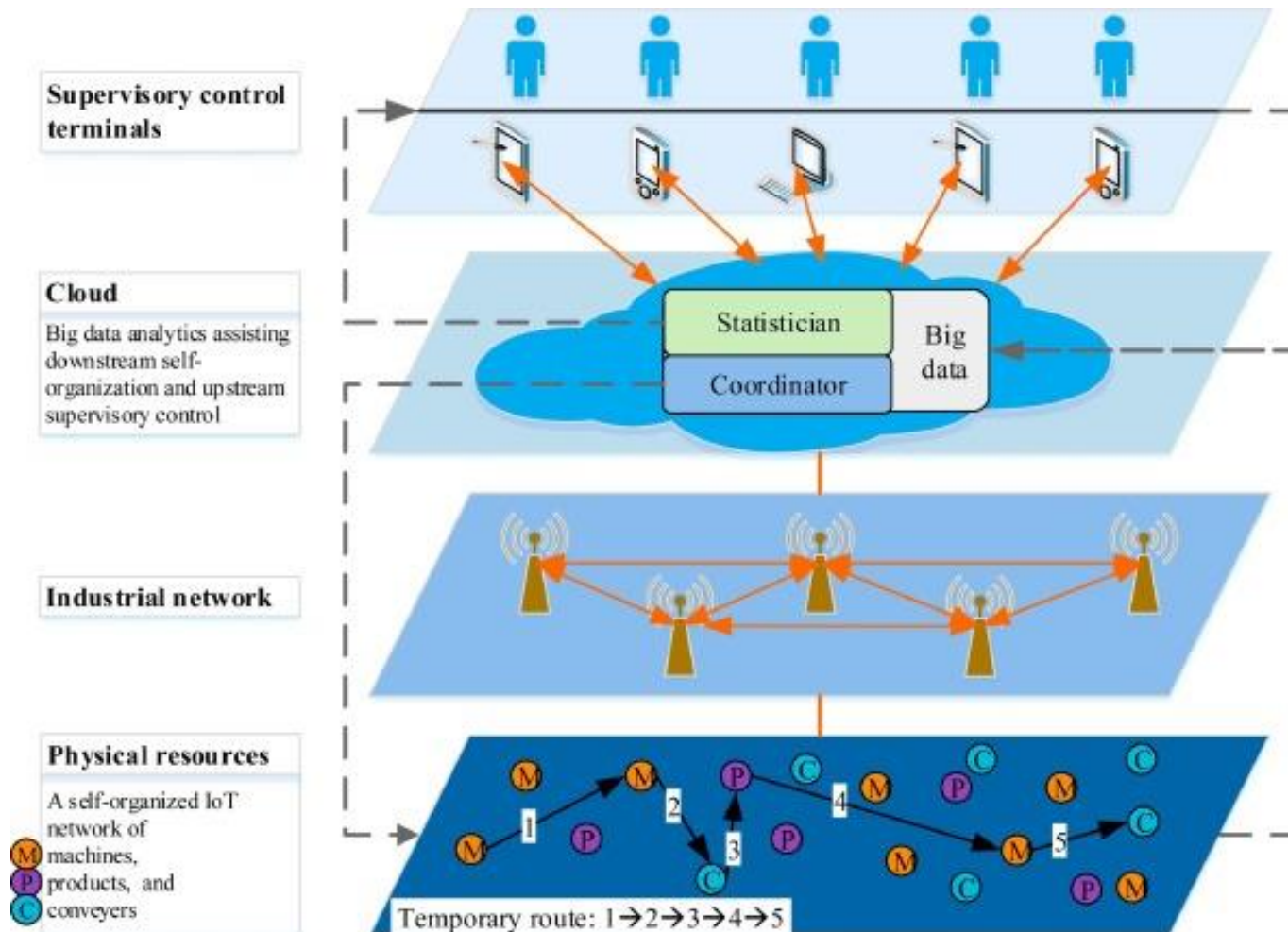
- Industry 4.0 and Supply Chain Management
- Intelligent Sustainable Supplier Selection
- The Developed MAS Approach
- MAS Approach Applicability Experiment
- Theoretical and Managerial Implications
- Contributions, Final Remarks and Future Work

# History of Production

## Managing the increasing complexity

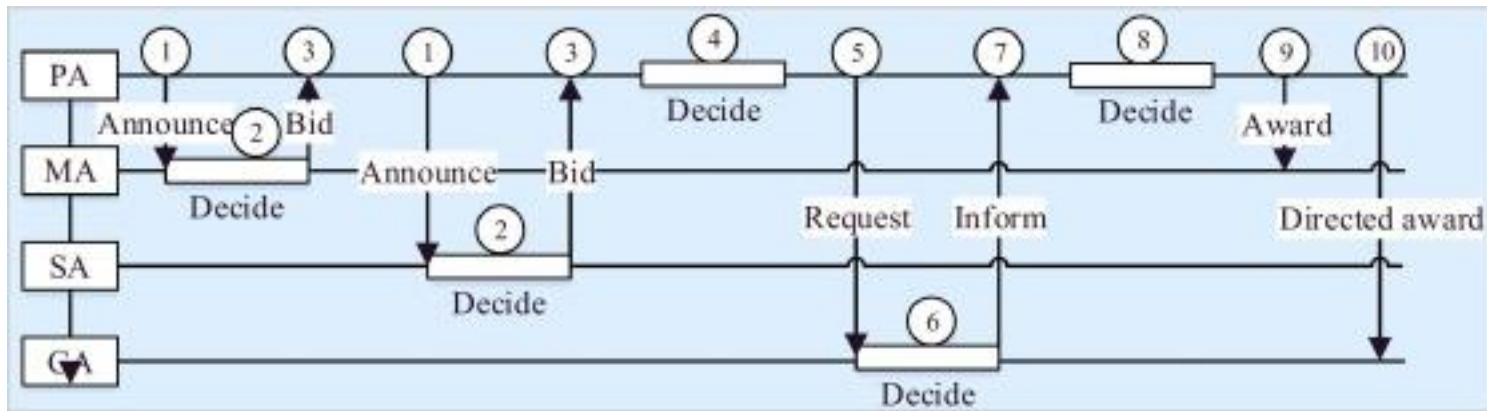


# Industrial 4.0



Wang, Shiyong, et al. "Towards smart factory for Industry 4.0: A self-organized multi-agent system with big data based feedback and coordination." *Computer Networks* 101 (2016): 158-168.

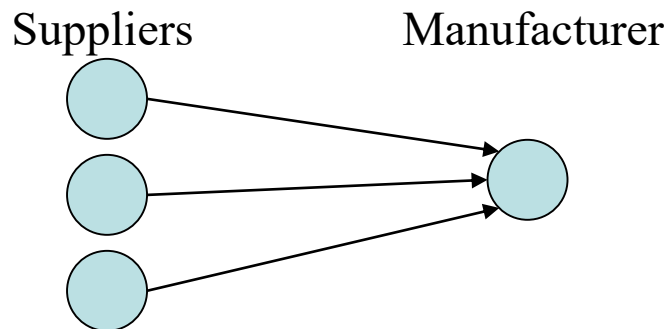
# Multi-Agent Systems



“smart factory is characterized by a self-organized multi-agent system”

Wang, Shiyong, et al. "Towards smart factory for Industry 4.0: A self-organized multi-agent system with big data based feedback and coordination." *Computer Networks* 101 (2016): 158-168.

Develop MAS between Supplier and Manufacturer For Supplier Selection



# Research Objectives

## Contribution and novelty of this work,

- developing a **MAS approach** applied to the process of supplier evaluation and order allocation in order to formulate appropriate linkages between the upstream members of a supply chain (buyer-supplier)
- considering the sustainability **TBL attributes** in the process of supplier evaluation and incorporating them into the order allocation process.
- developing **efficient models and methodologies** for sustainable supplier evaluation and selection process.
- proposing a **sustainability incorporated bi-objective multi period, multi products order allocation mathematical model.**
- offering a **comprehensive and unified classification** of criteria and sub criteria related to three pillars of sustainability that are **environmental, economic and social.**

# Phases of Sustainable Supplier Selection and Order Allocation

**Problem formulation**

- ✓ Determine the required products

**Criteria formulation**

- ✓ Formulate the sustainable supplier evaluation criteria

**Requirement gathering phase**

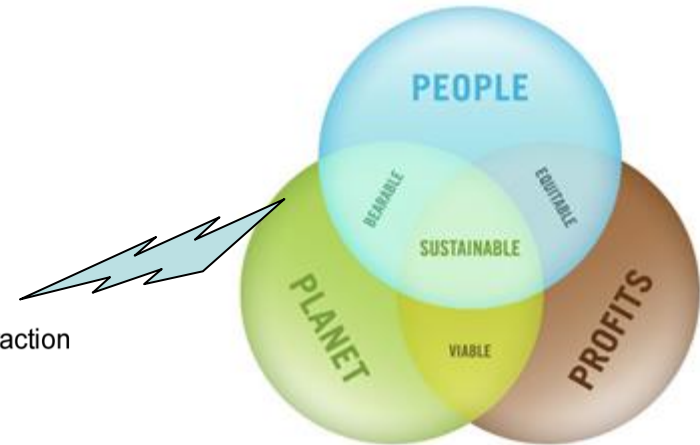
- ✓ Gather the required data through a user interaction interface

**Supplier evaluation phase**

- ✓ Obtain the weights for the defined criteria
- ✓ Calculate the sustainable suppliers performance score

**Order allocation phase**

- ✓ Minimize the total purchasing costs
- ✓ Maximize sustainable suppliers performance score
- ✓ Allocate orders to the sustainable suppliers



**Triple Bottom Line**

# MAS Approach Design for SSS&OA process

## Agents:

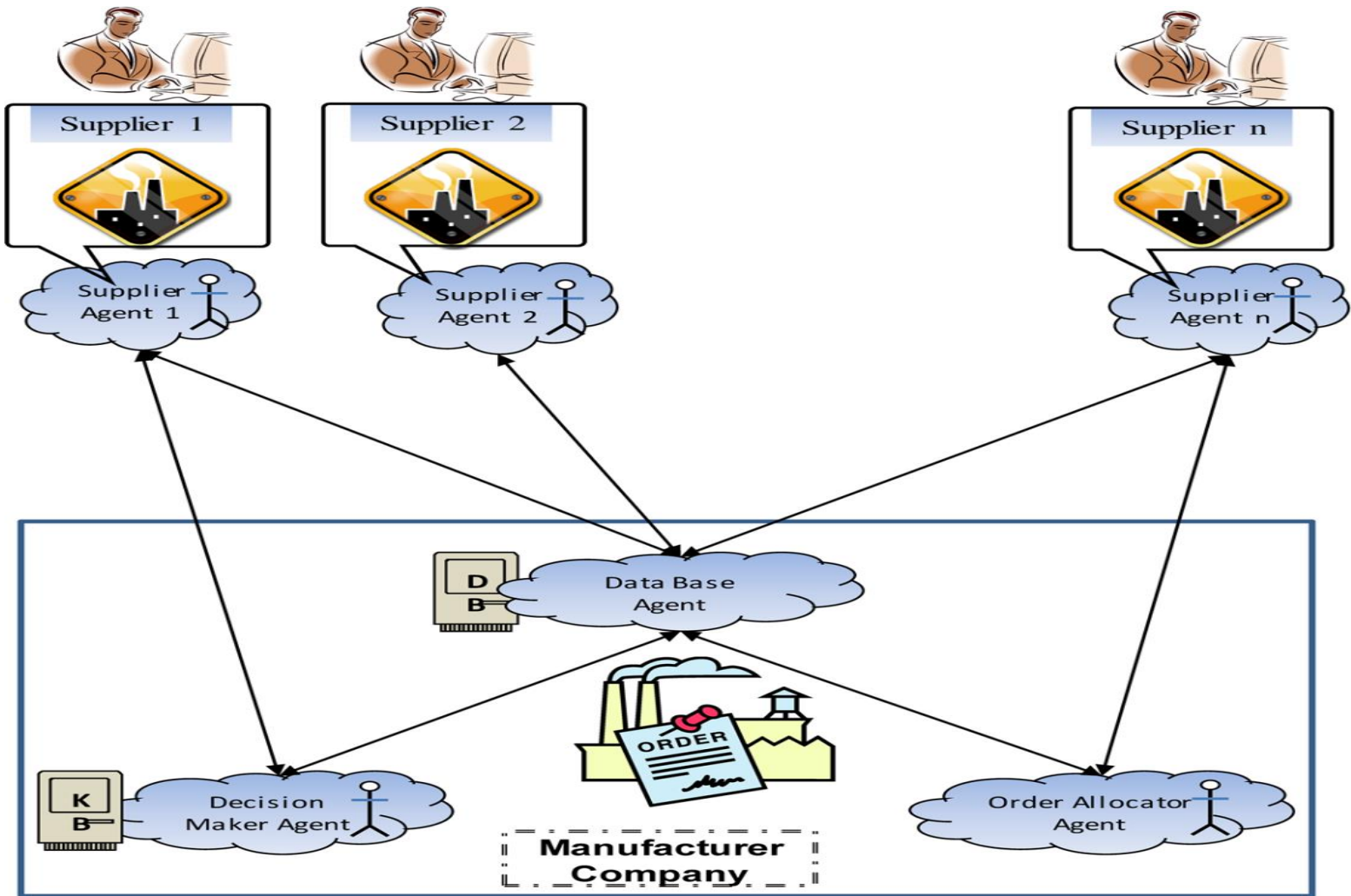
- Database Agent (DBA)
- Supplier Agent(s) (SA)
- Decision Maker Agent (DMA)
- Order Allocator Agent (OAA)

## Roles

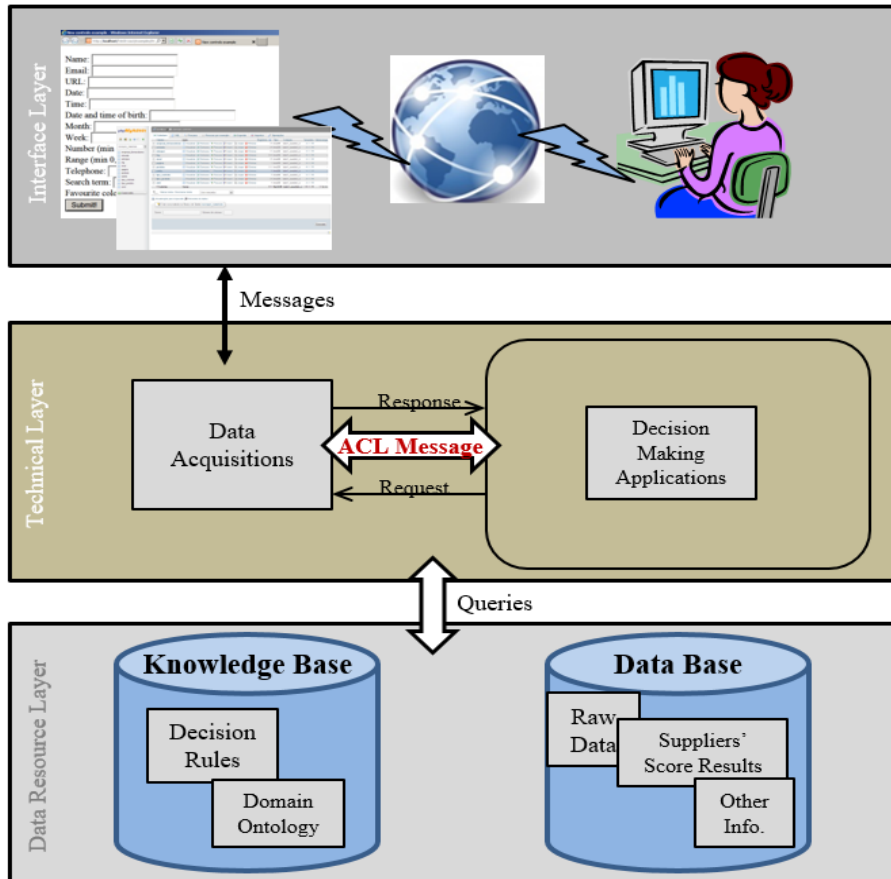
- Initiate the evaluation and order allocation processes.
- Determine the optimal order quantities by the order allocation model and solution approach.
- Save and retrieve input and output information into the DB.
- Evaluate the suppliers by the proposed supplier evaluation algorithm.



# Agents Network

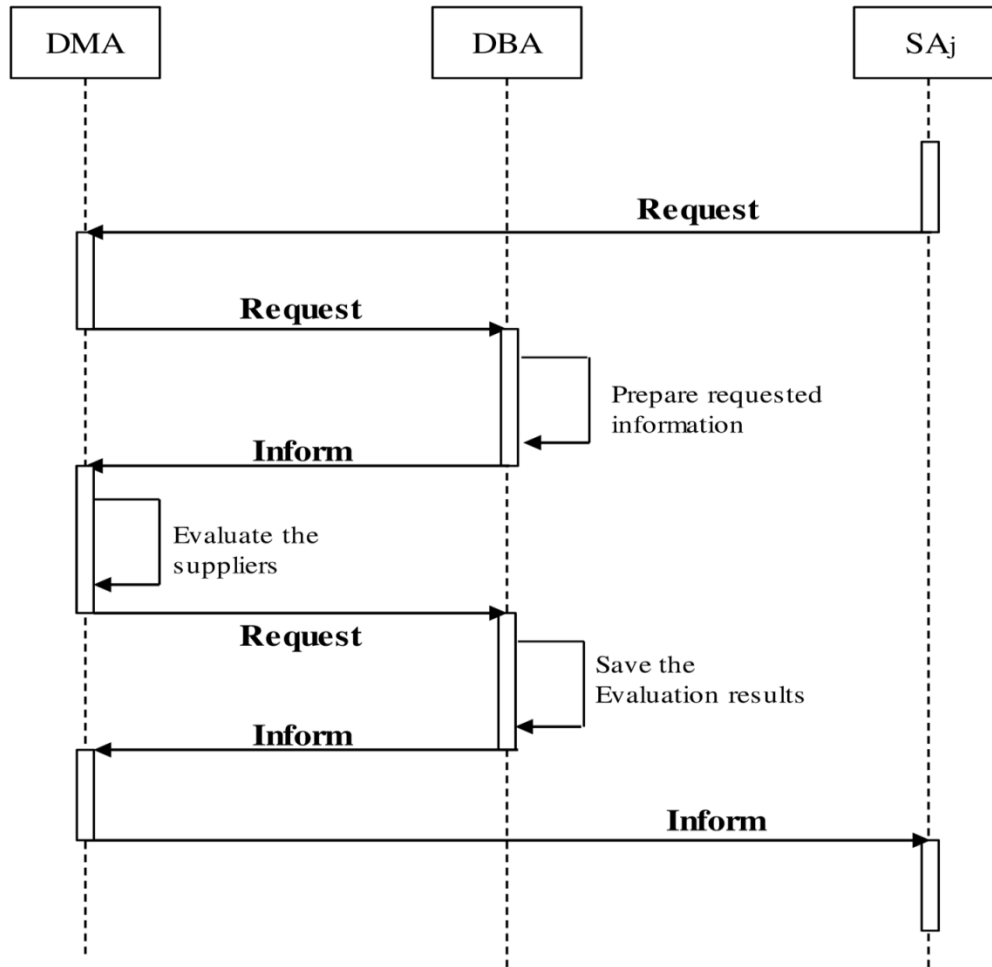


# Three Layer Architecture



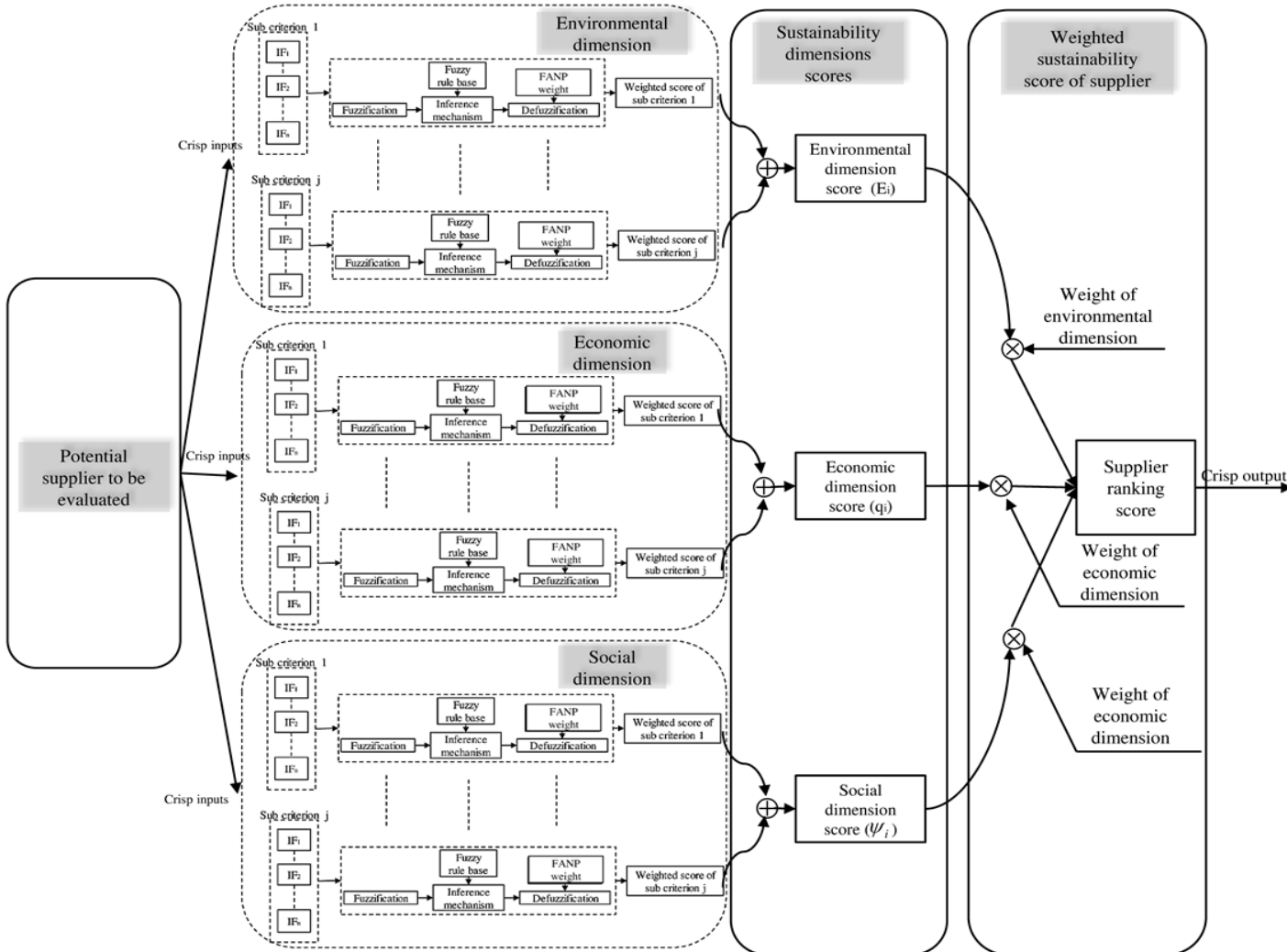
Agent	Responsibilities
SA	<ol style="list-style-type: none"> <li>1) Serve as user-agent interaction facility to receive supplier's input data.</li> <li>2) Sends the sustainable supplier evaluation input data to the DBA.</li> <li>3) Receives a confirmation from the DBA regarding input data being received.</li> <li>4) Requests the DMA about the results of evaluation.</li> <li>5) Receives the sustainability performance score from DMA.</li> </ol>

# Sustainable Supplier Evaluation Process Interaction Scheme



- Methodology used: Foundation for Intelligent Physical Agents (FIPA)
- FIPA allows communication between agents
- MAS developed in Java Development Framework (JADE)
- Example shows communication between the Decision Maker Agent (DMA), Data Base Agent (DBA) and the Supplier Agent (SA)

# Fuzzy Inference System (FIS) Model for Sustainable Supplier Evaluation



Extent analysis method on Fuzzy AHP (Chang 1996)

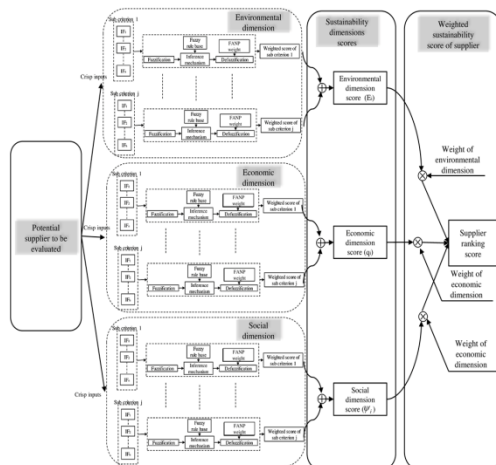


# Order Allocation Model for Making Sustainable Sourcing Decisions

**Total Purchasing Cost (TPC) objective function:**

$$\text{Min } Z_1 = \sum_{i=1}^m \sum_{j=1}^n P_{ij} X_{ij} + \sum_{j=1}^n o_j Y_j + \sum_{i=1}^m \sum_{j=1}^n o'_j X_{ij} + \sum_{i=1}^m \sum_{j=1}^n h_i P_{ij} (X_{ij} / 2) + \sum_{j=1}^n tc_j n_j$$

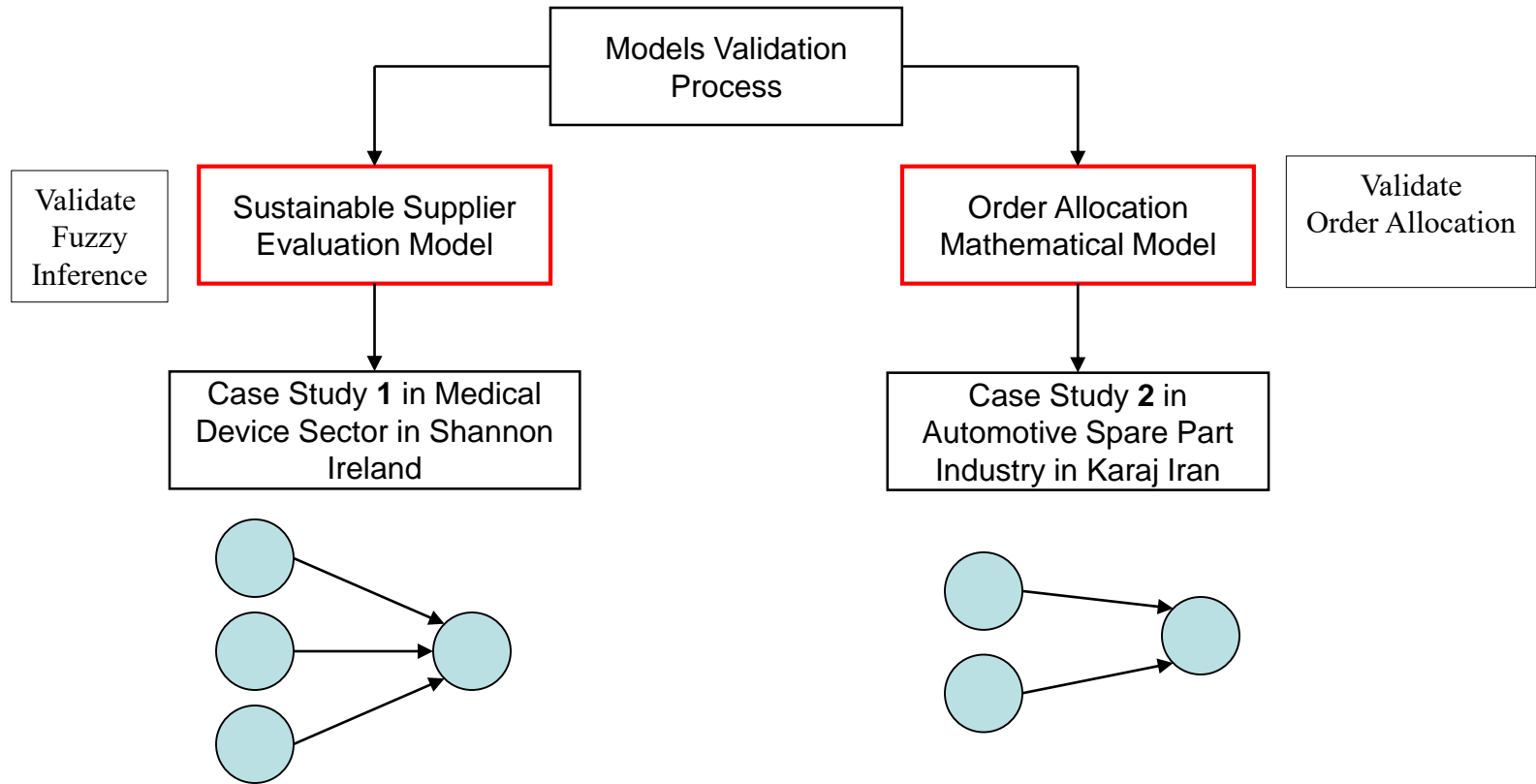
**Supplier Sustainability Performance value (SSPV) objective function:**



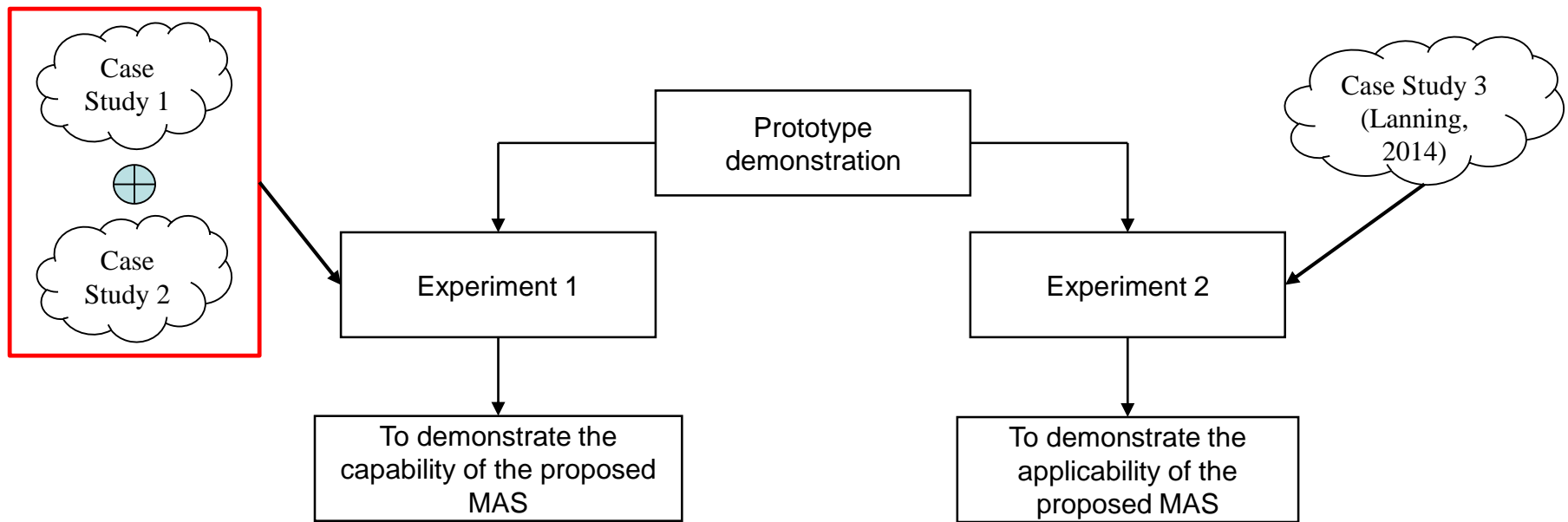
$$\text{Max } Z_2 = \sum_{i=1}^m \sum_{j=1}^n sp_j X_{ij}$$

Solved using the max-min approach by Amid, Ghodspour et al. 2011

# Models Validation through Two Separate Case Studies

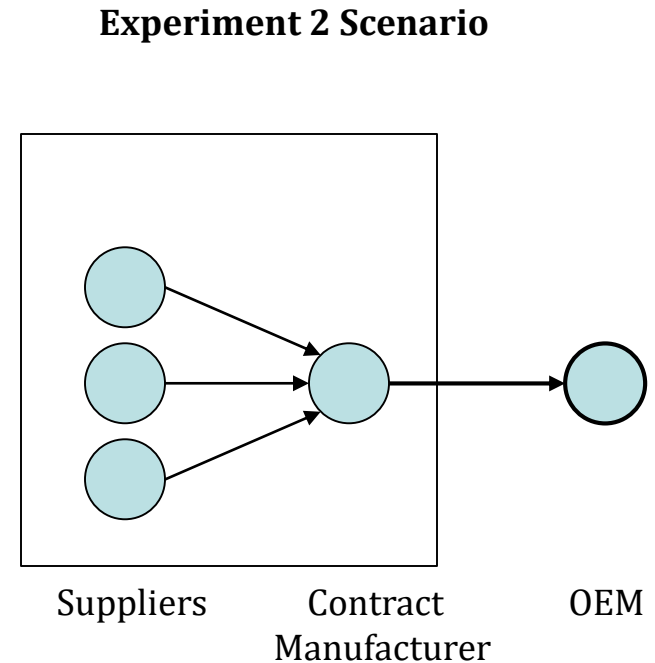
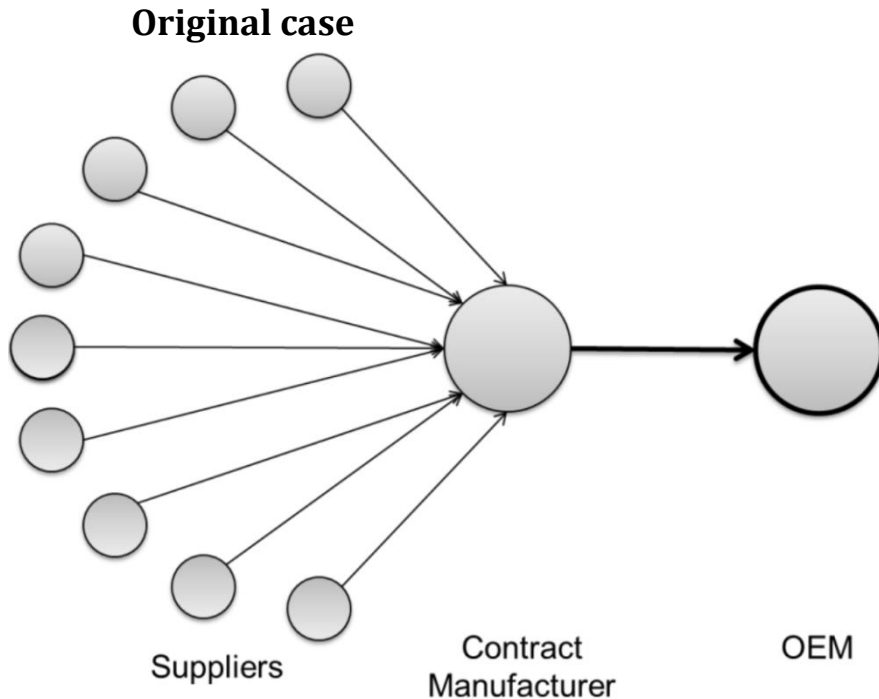


# Implementation of the Developed MAS Approach on JADE



Capability & Application

# Experiment 2: an Application Scenario (Case Study 3)



Just with the contract  
manufacturer

- Weekly basis demands and orders.
- Amount of information flows and communications.
- Human interaction.



# Theoretical implications, conclusions and future works

- Data-centric approaches cf. Industry 4.0
- Interoperability, decentralization, real-time capability and service orientation
- MAS narrows challenges using a decentralized system, which provides appropriate information to the right member of the SC in the right time and in a timely manner
- Non-technical perspective, a challenge also lies in establishing trust among supply chain partners
- MAS approach has the potential to narrow the communication and information exchange issues with respect to the sustainable supplier evaluation process

Thanks



# Publications

- Ghadimi, Pezhman, A. H. Azadnia, C. Heavey, A. Dolgui and B. Can (2015). “A Review on the Buyer–Supplier Dyad Relationships in Sustainable Procurement Context: Past, Present and Future.” *International Journal of Production Research*. pp. 1-20.
- Ghadimi, Pezhman, Ahmad Dargi, and Cathal Heavey. "Making sustainable sourcing decisions: practical evidence from the automotive industry." *International Journal of Logistics Research and Applications* (2016): 1-25.
- Ghadimi, Pezhman, Ahmad Dargi, and Cathal Heavey. "Sustainable supplier performance scoring using audition check-list based fuzzy inference system: a case application in automotive spare part industry." *Computers & Industrial Engineering* (2017).
- Ghadimia, Pezhman, Farshad Ghassemi Toosi and Cathal Heavey “A Multi-Agent Systems Approach for Sustainable Supplier Selection and Order Allocation in a Partnership Supply Chain”, Submitted *European Journal of Operational Research*

# Publications

- Pezhman Ghadimi, and Cathal Heavey (2013). "A Review of applications of agent-based modelling and simulation in supplier selection problem." In 2013 8th EUROSIM Congress on Modelling and Simulation (EUROSIM), pp. 101-107
- Pezhman Ghadimi, and Cathal Heavey (2014). "Masos: a multi-agent system simulation framework for sustainable supplier evaluation and order allocation." In Proceedings of the 2014 Winter Simulation Conference, pp. 1132-1143
- Pezhman Ghadimi, and Cathal Heavey (2014). "Sustainable Supplier Selection in Medical Device Industry: Toward Sustainable Manufacturing." Procedia CIRP 15: 165-170.