PhD Open Days

Design and planning of sustainable supply chains

LEADERS FOR TECHNICAL INDUSTRIES
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Main objectives

- Study the impact of the three pillars of sustainability on both strategic and tactical supply chain decisions
- Derive strategies towards a more sustainable supply chain

Motivation

- Supply chain sustainability policy definition constitutes a major challenge.
- Most literature focuses only on the economic and environmental pillars of sustainability. Literature on the social pillar is very infrequent, mainly due to lack of data and quantifiable indicators.
- EC funding for 2014-2020: Up to €376 billion for fostering growth and promoting job creation in the less developed European regions
- The complexity of the problem requires the use of powerful decision support tools that can incorporate a high number of variables and offer easier and faster visualization of the impacts of sustainability policies.

ToBloOM – Triple Bottom Line Optimization Modelling - is proposed to fill this gap.

ToBLoOM

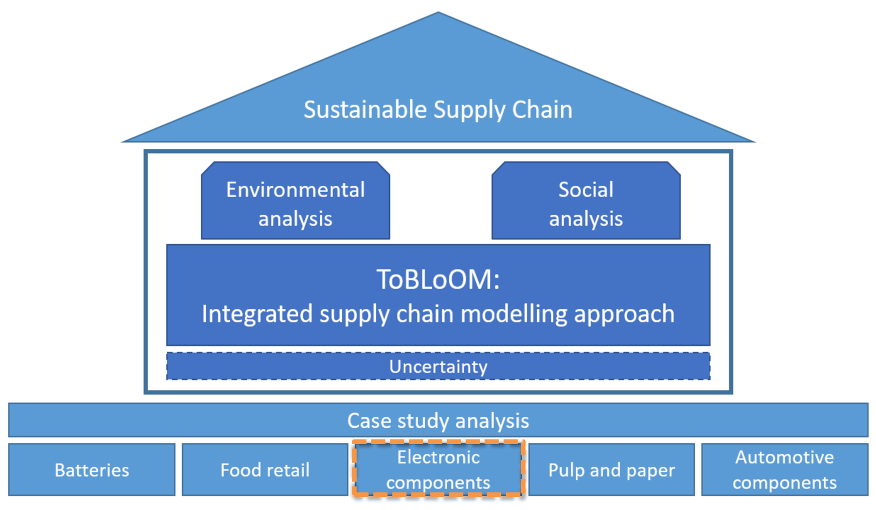

Figure 1: Conceptual framework.

Table 1: ToBLoOM's inputs and outputs.

Possible superstructure (alternative locations)	Suppliers Factories Distribution centers Clients Recovery centers
Entities	Capacities Installation costs Necessary manpower (fixed and capacity dependent)
Alternative production technologies	Capacities Operating costs Necessary manpower
Products (raw materials intermediate products, final products, recovered products)	Bill of materials Costs Physical characterization
Alternative transportation modes	Costs Necessary manpower
Demand	

Echelons	Supply	Production	Warehousing	Use	Collection and sorting
Decisions	Supplier selection	Number and location of facilities	Number and location of facilities	Product recovery strategy	Number and location of facilities
	Supplier allocation	Production capacity installation	Storage capacity installation		Remanufacturing capacity installation
	Raw material purchasing levels	Production allocation	Inventory levels		Remanufacturing allocation
		Production planning			Remanufacturing planning
		Technology selection and allocation			Technology selection and allocation
	Transportation network definition				
	Flow levels				

Case-study

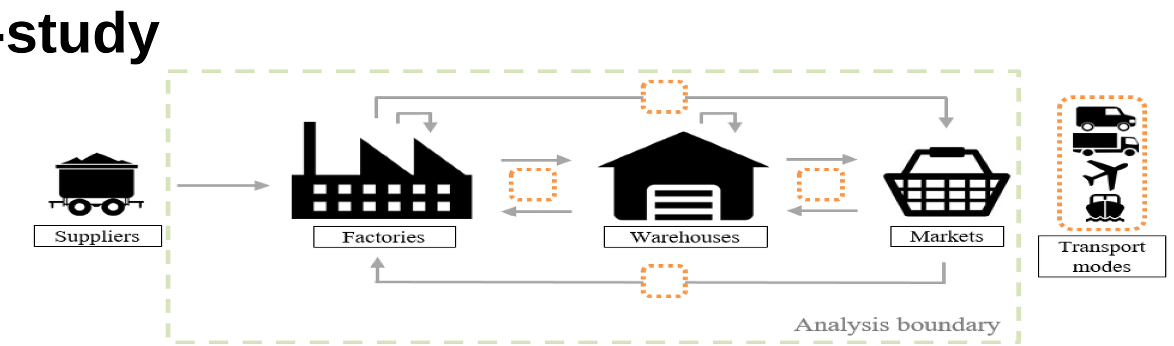

Figure 2: Case-study network representation.

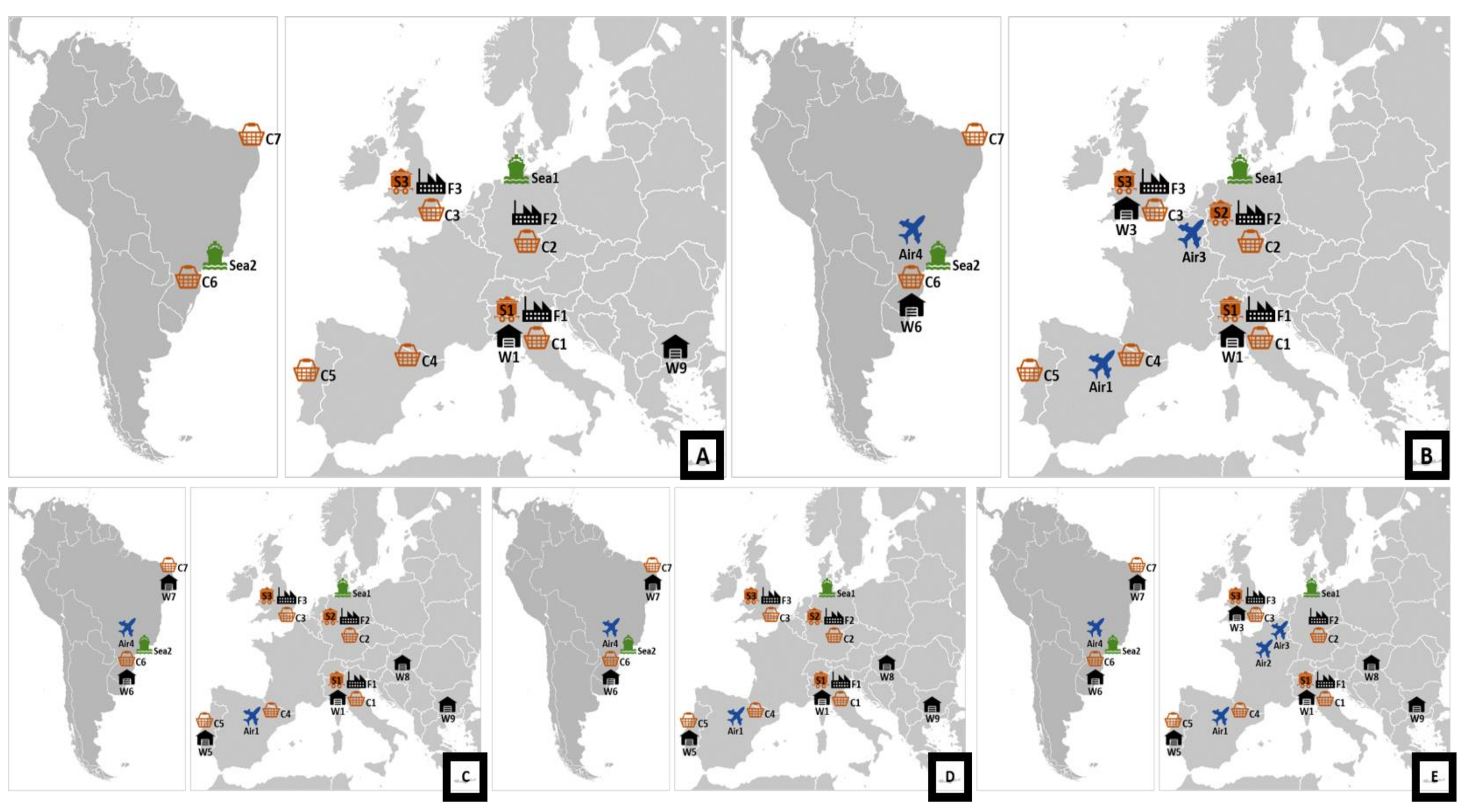

Figure 3: Superstructures obtained for each of the cases analysed: A – NPV maximization, B – environmental impact minimization, C and D – social benefit maximization within a 5% and 15% maximum reduction on NPV, respectively; E – social benefit maximization.

Table 2: Decisions' results summary.

	Cases				
	A	**B**	**C**	**D**	**E**
Factories	Factory in Verona is installed with maximum capacity. Factories in Hannover and Leeds are installed with 8% and 19% of maximum capacity, respectively.	Factory in Verona is installed with maximum capacity. Factories in Hannover and Leeds are installed with 43% and 39% of maximum capacity, respectively.	Factory in Verona installed with maximum capacity. Factory in Hannover installed with minimum capacity. Factory in Leeds installed with 15.95% of maximum capacity.	Factory in Verona installed with maximum capacity. Factory in Hannover installed with minimum capacity. Factory in Leeds installed with 16.16% of maximum capacity.	All installed with maximum capacity.
Warehouses	Verona Sofia	Verona Leeds São Paulo	All but Hannover, Leeds and Zaragoza installed with maximum capacity.		All but Hannover and Zaragoza installed with maximum capacity.
Suppliers	82% supplied from Verona 18% from Leeds	64% supplied from Verona 12% from Hannover 24% from Leeds	71% supplied from Verona 10% from Hannover 19% from Leeds	64% supplied from Verona 18% from Hannover 18% from Leeds	84% supplied from Verona 16% from Leeds
Supplier's allocation	Supplier in Verona supplies almost entirely factories in Verona and Hannover. Factory in Leeds supplied by both Leeds (75%) and Verona (25%).	Factories are supplied in totality by closest supplier.	Most of the supply (70-100%) is performed by closest supplier. Mostly Verona supplies the remaining amount. .		Supplier in Verona supplies almost entirely factories in Verona and Hannover. Factory in Leeds supplied by both Leeds (76%) and Verona (24%).
Production	Alternative production technologies are preferred.				
	Most production of *fp1* is in Verona (46-54%).				
	Most production of *fp2* is divided between Hannover (46-56%) and Leeds (30-48%).				
Remanufacturing	Most remanufacturing of rp1 is performed in Leeds (89%). Most remanufacturing of rp2 is performed in Hannover (48%).	Divided between Hannover and Leeds.	Mostly performed in Leeds (52%/56%). The remaining is divided between Verona and Hannover.		Mostly performed in Leeds (72%/86%). The remaining is divided between Verona and Hannover.
Product recovery	Minimum possible (15%)	81% for fp1 Minimum possible for fp2	Minimum possible.	15% for fp1 16% for fp2	21% for fp1 25% for fp2
Inventory	More inventory of fp1 is kept than of fp2				
	Divided between Verona and Sofia.	Most inventory of fp1 is kept at São Paulo (44%) and fp2 at Verona (46%).	Most inventory of fp1 is kept at Lisbon (47%) and fp2 at Budapest (73%).	Most inventory of fp1 is kept at Lisbon (43%) and fp2 at Verona (37%).	Inventory is distributed among the seven warehouses.
Transportation	Mostly trucks of bigger capacity are purchased (15 versus 8).	Mostly trucks of bigger capacity are purchased (36 versus 3).	Mostly trucks of smaller capacity are purchased.		
	Air transportation is not used.	Air transportation is used for some intercontinental (Spain-São Paulo and Belgium-São Paulo) and intracontinental transportation (connecting Belgium-Spain).	Air transportation is only used for intercontinental transportation (Spain-São Paulo).		All links are established.
	Sea transportation is used in all cases.				

SC structure varies with sustainability objective.

Product recovery strategies should vary with type of product.

Intermodal transportation is environmentally beneficial but only in specific connections.

Conclusions

The developed and presented tool provided support for decisions to be taken both internal and external to the company and at several levels of the supply chain. Specifically it allowed to:

- Understand the connections between the different supply chain activities and because of that obtain a better combined performance across the supply chain. This would not be possible if we were only considering the commonly published location-allocation supply chain decisions.
- Understand the impact of these decisions on the three pillars of sustainability and from there derive potential strategies that can reduce the trade-offs between these pillars.
- Identify environmental sustainability hotspots and prioritize actions to reduce the environmental impact of the supply chain activities (not shown).
- Explore socially responsible alternatives without compromising either the economic performance of the company or the potential funding bodies (not shown).
- Derive potential improvement strategies and study its impact across supply chain activities as well as on the three pillars of sustainability (not shown).
- Design and plan a supply chain capable of accommodating parameters' uncertainty (e.g. market penetration) through a stochastic approach (not shown).

It was concluded that changes in optimization objectives return significantly different strategic and tactical decisions. The importance of an integrated framework was demonstrated – allows a better performance across the supply chain.

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