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Impact of collaboration cluster formation on carbon and cost savings in Horizontal Collaboration

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Introduction

- 30% of vehicle-kilometres are running empty and vehicles are utilised to only 61% of their weight capacity in the UK (Department of Transport, 2019)
- An effective way of improving vehicle utilisation is through **horizontal collaboration** among companies in road freight transport (Hingley et al. 2011, Rodrigues et al. 2015)
- Horizontal collaboration has potential for coalition gains up to **30% cost savings** and up to **54% carbon savings** in road freight transport (Guajardo et al., 2018; Vanovermeire et al., 2014; Lozano et al., 2013)
- 'Determining and Dividing gains' in horizontal collaboration of road freight transport (Cruijssen 2007, Lozano et al., 2013, Guajardo and Rönnqvist, 2015)

Research Focus:

1) Develop a framework to identify coordination costs of horizontal collaboration

2) Identify which coalition formations are likely to achieve the lowest cost and carbon emissions when the coordination costs are taken into account in the UK FMCG sector

Literature Review…

- **Horizontal collaboration in the UK FMCG sector**
  - Vertical collaboration is more common compared to horizontal collaboration
  - Companies are faced with increased complexities in their secondary distribution
- **Cost and carbon allocation in horizontal collaboration**
  - Lack of transparency caused collaborations to fail (Cruijssen *et al*., 2007)
  - Cooperative game theory (CGT) provides a framework which is relevant to study cost allocation problems.
  - CGT analyses
    - **a set of possible outcomes**
    - **studies what participating organisations can achieve**
    - **which coalitions can form**
    - **how gains can be divided in coalitions**
    - **whether outcomes are robust, fair and stable (Nagarajan and Sošić, 2008)**
  - Some studies have focussed on coalition formation and determining/dividing gains through CGT (Lozano et al., 2013; Guajardo and Rönnqvist, 2015; Jouida et al., 2017; Xu et al., 2017; Guajardo et al,. 2018). CGT application in logistics:
    - **Vanovermeire and Sörensen (2014) – reward organisations in a collaboration that can provide flexibility in delivery time windows**
    - **Lozano *et al.*, (2013) – benefits shippers may achieve by merging their transport flows**
    - **Frisk *et al.*, (2010) - calculated transportation cost in backhaul of a collaborative forest transportation problem**
    - **Krajewska *et al.*, (2008) - analysed cost reduction opportunities that freight carriers can receive by forming a coalition**

…Literature Review

- Allocation CO_2 emissions to cooperating partners (Naber et al., 2015; Zhu et al., 2016).
- CO_2 emissions are applied as a part of the cost function for carbon allocation (Özener, 2014; Niknamfar and Niaki, 2016; Sanchez et al., 2016).
- The Shapley value is the average marginal cost of participating players, if the participants are entered in a random order (Shapley, 1953). It aims to distribute the gains from coalition in a fair manner. Application of shapley value (Krajewska et al. 2008; Cruijssen et al. 2010; Frisk et al. 2010; Lozano et al. 2013;Vanovermeire and Sörensen 2014).
- However, many collaborations fail in real world and barriers limit scalability of collaboration.

Research Gap –

- As the size of a collaborative group grows, coordinating cooperation will become more difficult as coordination cost increased (Lozano et al., 2013; Guajardo et al,, 2015)
- Less focus on **coordination costs in literature which has** the potential to outweigh any benefits from small sized companies

What are coordination costs?

- **Buyer Supplier:** In the case of a manufacturer–supplier dyad it might include *costs of exchanging information on products, price, availability, demand, as well as the costs to exchange design changes rapidly with the supplier (*Um and Kim, 2019; Simatupang and Sridharan, 2005; Grover and Malhotra, 2003).
- **Outsourcing:** Coordinating mechanisms may include *sharing forecasts* and *schedules*, using *standardized information systems*, and relying on *personal or group communication* and *socialization* (Handley and Banton, 2013; Dibbern et al., 2008; White and Lui, 2005). Coordination represent the *time, effort, and resources* the outsourcing organization expends to coordinate with the service provider effectively

Coordination Costs – Transaction Cost Economics

Identifying partners for collaboration

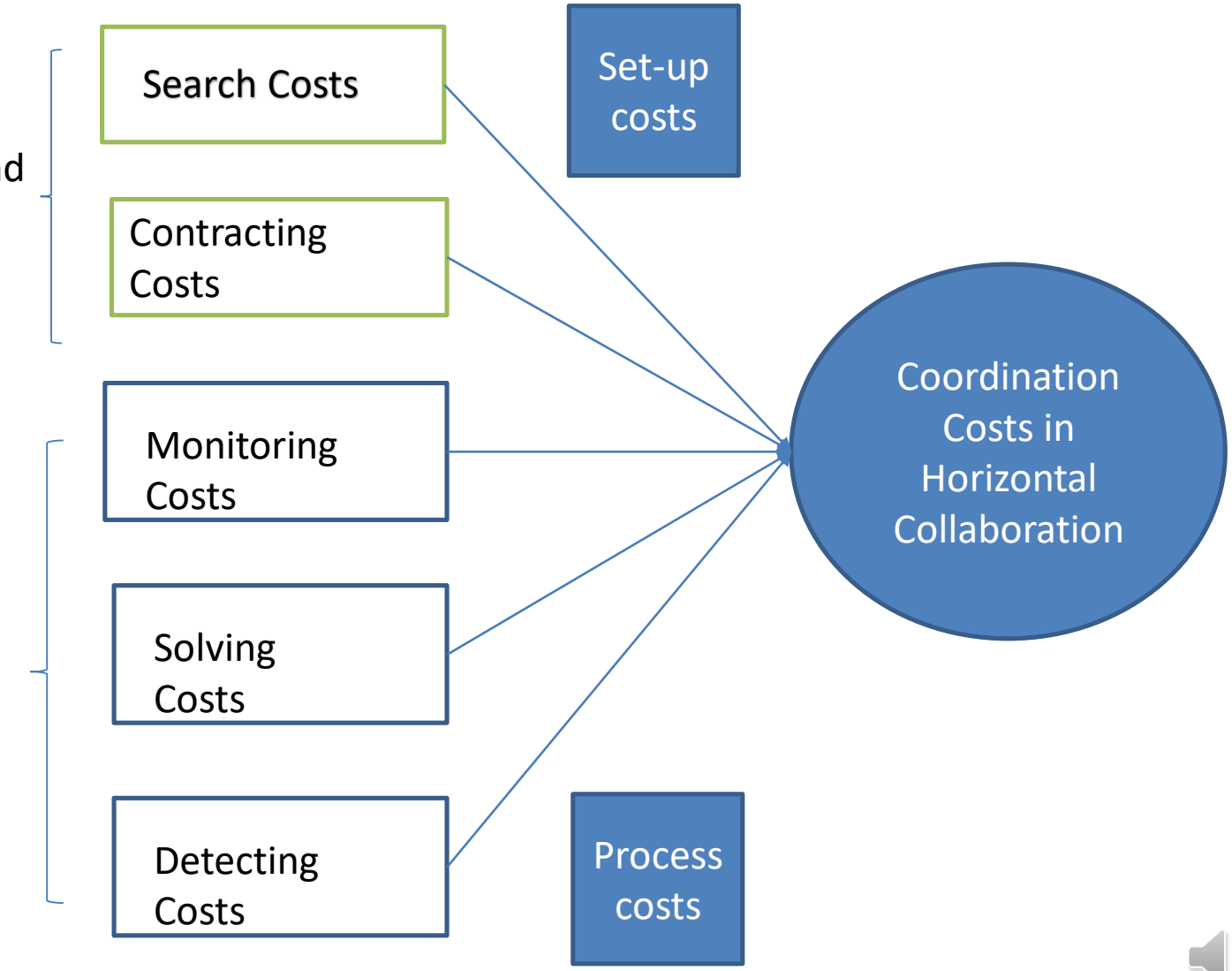
Development of contracts (Contractual and Relational)

- Sharing of resources (transport/warehouse)
- Sharing of Information
  - Data and IT systems
- Logistics administration
- Transport packaging and handling

Monitoring behaviour of companies

Standard solutions

Legal action costs



Methodology

Data Collection

- Data collected from 27 FMCG companies during a month in 2010 for a project called ‘STARFISH’
- Origin and destination postcodes, the frequency of movements between origins and destinations, quantities moved, vehicles with carrying capacity and storage type

Data Analysis

- Average loads of 15 pallets or less, were extracted from the given dataset
- Cluster analysis was used to identify depots in close proximity within a radius of 35km to deliver to customers postcodes
- The transport costs for individual transport flows were calculated using a network design tool based on heuristics algorithm and linear programming
- The cost and carbon savings were generated by bundling of individual transport flows

Cost and Carbon Allocation Method

- Cost savings and carbon savings were identified, these cost savings were distributed among participating companies applying the ‘Shapley Value’
- Incremental convex function applied to simulate coordination costs to identify coalition formation and cost gains

Shapley Value…?

$$\phi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!\,(n - |S| - 1)!}{n!} \left(v(S \cup \{i\}) - v(S)\right)$$

where

- $\phi_i(v)$ is the amount player i gets in coalition game
- N is a finite set of companies forming a grand coalition (N = {*1,2….n*})
- S is a set of coalitions in N
- $\frac{|S|!(|N|-1-|S|)!}{|N|!}$ is the possible ways a coalition can be formed
- $[v(s \cup \{\mathrm{i}\}) - v(s)]$ is the marginal contribution of player i in coalition N

Properties of Shapley value -

1) **Efficiency -** total value of the grand coalition should be allocated to the players
2) **Individual Rationality -** players should be better off in a collaboration
3) **Symmetry** - if two players contribute the same to each coalition then the solution should treat them equally
4) **Dummy player** - value should be zero
5) **Additivity -** values of two games sum up to the value computed for the sum of both games

Coordination Cost Calculation:

V(S) = CS (S) – CC(S)

Where

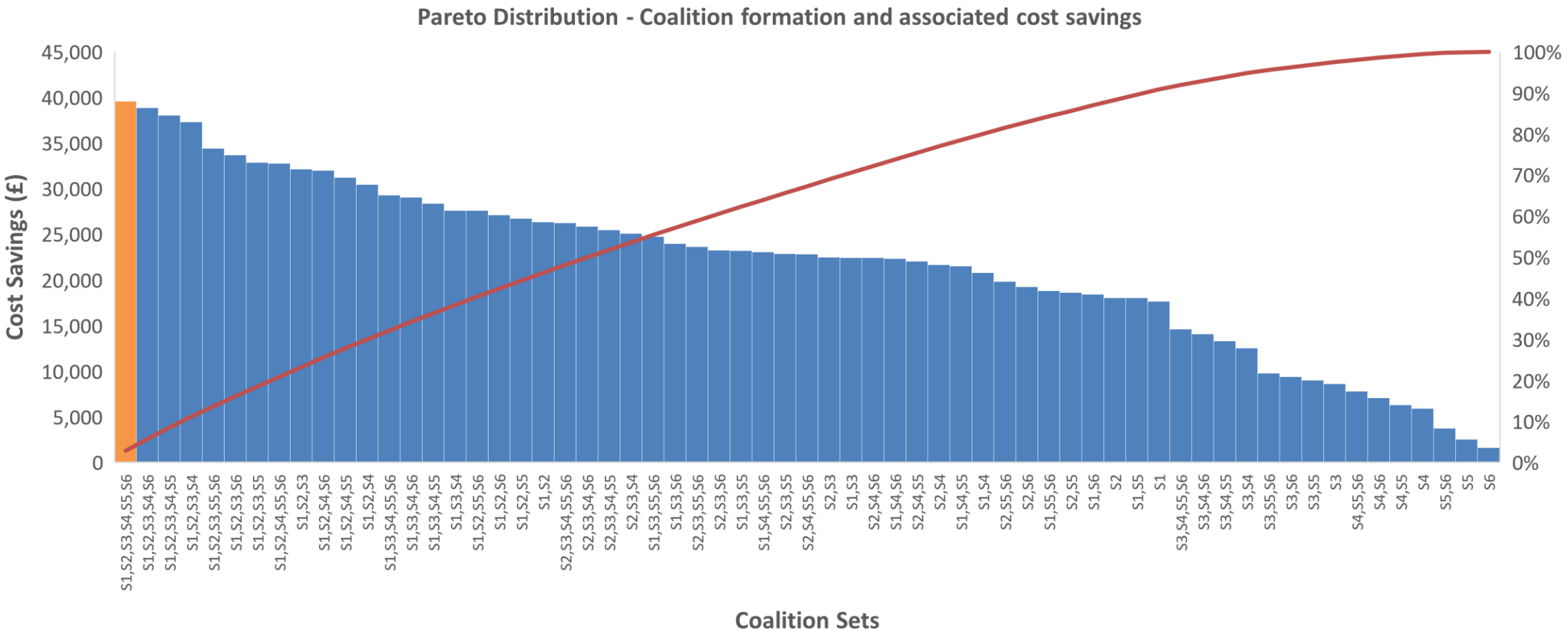
CS(S) = Coalition Savings

CC(s) = Coordination costs

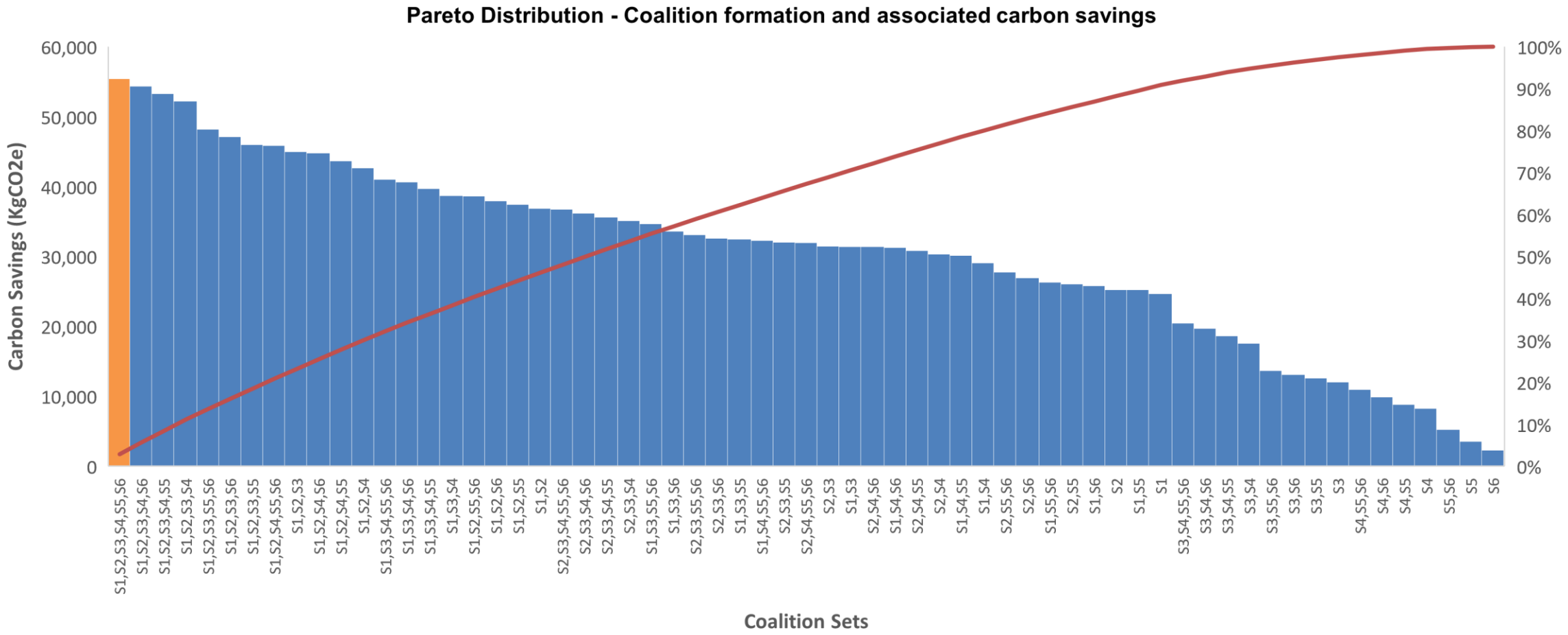
Incremental Convex function:

$$f(\boldsymbol{S}) = \alpha \frac{|\mathbf{s}|(|\mathbf{S}| - 1)}{(|\mathbf{S}| + 1)}$$

Coalition Formation and Cost Savings



Coalition Formation and Carbon Savings

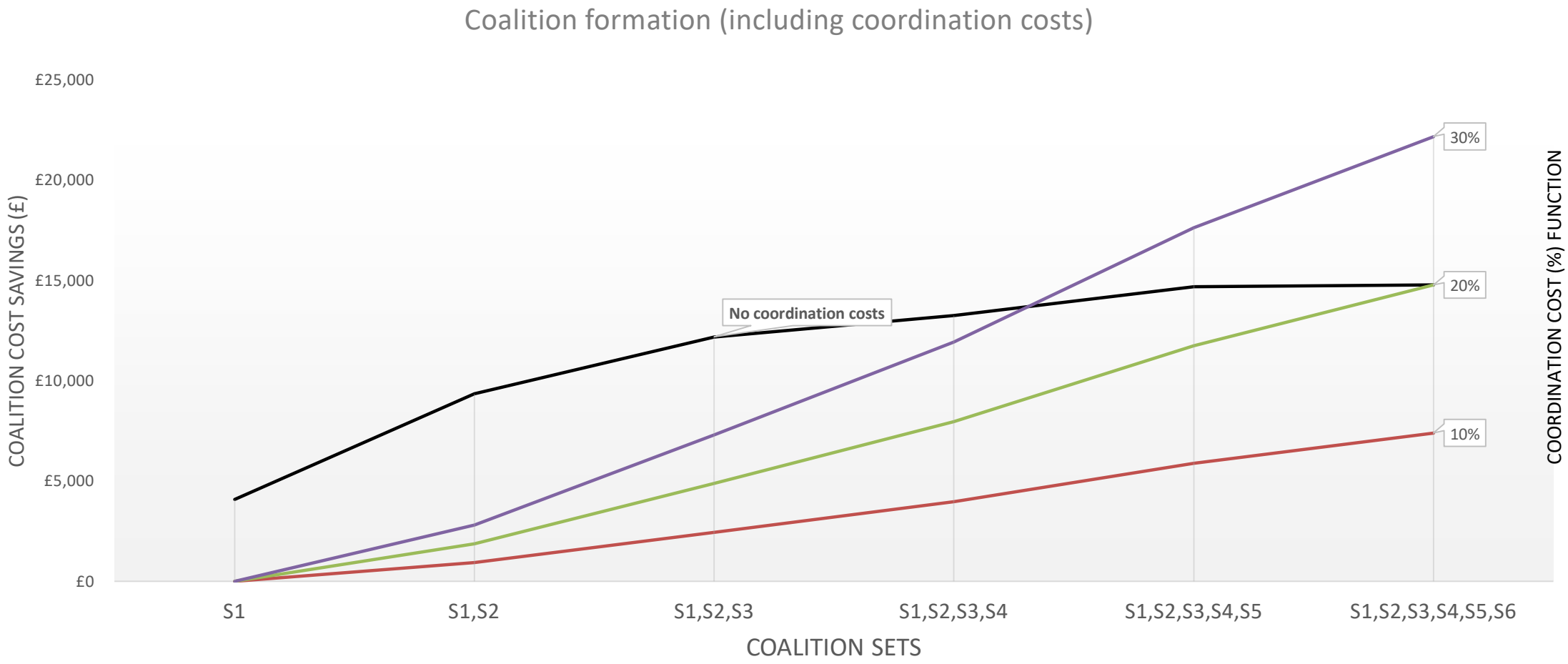


Cost and carbon allocation of 6 FMCG companies

Company	Transport Costs (£)	Cost Allocation Savings (Shapley)	Carbon Emissions (KgCO2e)	Carbon Allocation Savings (KgCO2e)	% relative cost savings	% relative carbon Savings
S1	**£17,640**	£5,340	**28,223**	6,530	36%	28%
S2	**£18,042**	£4,080	**28,867**	8,541	28%	36%
S3	**£8,604**	£2,160	**13,767**	3,463	15%	15%
S4	**£5,919**	£1,572	**9,471**	2,084	11%	9%
S5	**£2,528**	£1,296	**4,045**	2,515	9%	11%
S6	**£1,628**	£324	**2,604**	520	2%	2%
Total	**54,361**	**14,772**	**86,977**			

Grand coalition cost savings: **27%** and Grand coalition carbon savings: **31%**

Coalition Formation and Coordination Costs



Discussion and Conclusion

- Cost and carbon savings were achieved by each player in a grand coalition
- Grand coalition can provide 27% cost savings and 31% carbon savings without coordination costs
- Collaboration clusters are likely to form
- Sub-coalitions are likely to form when coordination costs are higher or equal to 20%

Future Work

- Survey to understand coordination costs of collaboration in a coalition
- Cost allocation in backhauling and multi-drop deliveries with time windows

Thank you.. Any suggestions or feedback?

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