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## ► To cite this version:

Beatriz Andrés, Raquel Sanchis, Jacques Lamothe, Leila Saari, Frederic Hauser. Integrated production-distribution planning optimization models: A review in collaborative networks context. International Journal of Production Management and Engineering, 2017, 5 (1), p. 31-38. 10.4995/ijpme.2017.6807 . hal-01618007

**HAL Id: hal-01618007**

**<https://hal.science/hal-01618007>**

Submitted on 10 Jul 2018

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## Integrated production-distribution planning optimization models: A review in collaborative networks context

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**Abstract:** Researchers in the area of collaborative networks are more and more aware of proposing collaborative approaches to address planning processes, due to the advantages associated when enterprises perform integrated planning models. Collaborative production-distribution planning, among the supply network actors, is considered a proper mechanism to support enterprises on dealing with uncertainties and dynamicity associated to the current markets. Enterprises, and especially SMEs, should be able to overcome the continuous changes of the market by increasing their agility. Carrying out collaborative planning allows enterprises to enhance their readiness and agility for facing the market turbulences. However, SMEs have limited access when incorporating optimization tools to deal with collaborative planning, reducing their ability to respond to the competition. The problem to solve is to provide SMEs affordable solutions to support collaborative planning. In this regard, new optimisation algorithms are required in order to improve the collaboration within the supply network partners. As part of the H2020 Cloud Collaborative Manufacturing Networks (C2NET) research project, this paper presents a study on integrated production and distribution plans. The main objective of the research is to identify gaps in current optimization models, proposed to address integrated planning, taking into account the requirements and needs of the industry. Thus, the needs of the companies belonging to the industrial pilots, defined in the C2NET project, are identified; analysing how these needs are covered by the optimization models proposed in the literature, to deal with the integrated production-distribution planning.

**Key words:** Collaborative planning, Supply chain, Production planning, Distribution planning.

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### 1. Introduction

The usual way to proceed in many manufacturing enterprises involves dealing with the optimisation of different types of plans separately (e.g. production, and distribution). Nevertheless, this approach has associated a set of drawbacks, because it does not consider the limitations of the partners downstream.

This limits potential improvement at the enterprises level and discards the total supply chain profit. Researchers are more aware of analysing and designing approaches based on the combination of different functions in the supply chain (SC) into integrated optimisation models; according to Park (2005) the collaborative planning is significantly relevant for companies that adopted it. The research area of integrating production and distribution

planning is increasing its impact, due to its decisive contribution in the establishment of collaborative relationships among the enterprises of the same supply chain.

In this paper, we consider the distribution planning problem and its evolution towards the collaborative production and distribution planning in supply chain. A literature review is carried out with the main aim of identifying solutions that deal with both plans, including the isolated perspective (in which each plan, production and distribution are separately calculated) and the collaborative perspective, which jointly computes production-distribution plans. Moreover, it is analysed how the integrated production-distribution planning approaches provided in the literature deal with the requirements of the real industry. The analysis of industrial planning needs was possible with the Pilot partners participating in the H2020 Cloud Collaborative Manufacturing Networks (C2NET) research project.

The goal of C2NET Project is the creation of cloud-enabled tools for supporting the SMEs supply network optimization of manufacturing and logistic assets based on collaborative demand, production and delivery plans. C2NET Project will provide a scalable real-time architecture, platform and software to allow the supply network partners:

- to master complexity and data security of the supply network,
- to store and share product, process and logistic data,
- to optimize the manufacturing assets by the collaborative computation of production plans,
- to optimize the logistics assets through efficient delivery plans and
- to render the complete set of supply chain management information on the any digital mobile device (PC, tablets, smartphones) of decision makers enabling them to monitor, visualize, control, share and collaborate.

The objectives of the project are grouped in three categories: Technical, Functional and Exploitation. At the technical level C2NET objectives are focused on the (i) implementation of C2NET Data Collection Framework (C2NET DCF) for IoT-based continuous data collection from supply network resources; (ii) implementation of C2NET Optimizer (C2NET OPT) for the optimization of manufacturing and logistics assets of the supply network by the collaborative

computation of production, replenishment and delivery plans; (iii) implementation of C2NET Collaboration Tools (C2NET COT) for providing support to the collaborative processes of the supply network; and (iv) implementation of C2NET Cloud Platform (C2NET CPL) to integrate the data module, the optimizers and the collaborative tools in the cloud. At the functional level, the objectives lead to (i) provide new ways to securely store relevant information from supply network partners in public cloud, community cloud or private cloud, ensuring data security and provide the ability of data sharing and data analytics; (ii) provide new tools for supporting the supply network optimization of manufacturing and logistic assets; (iii) provide new tools to support decision-makers in collaborative processes with intuitive UIs that display in real-time the right data at the right time, built in advanced apps for mobile devices for selective management functionalities across the supply network; and (iv) provide a new cloud space for allowing the access to all the participants in the value chain to support their decisions and processes enhancement. Finally, the objectives related with the exploitation center its attention in (i) technological exploitation of new ICT tools developed by open its integration on existing and future software and its evolution as open source technologies; (ii) commercial exploitation of C2NET Platform and Tools providing the services to companies of any manufacturing sector and licensing the software to consultancy firms; and (iii) know-how exploitation of the new knowledge created during the research and innovation activities developed in the project providing consultancy and training to companies.

This paper focuses on the research of optimization of manufacturing and logistics assets of the supply network by the collaborative computation of production and delivery plans. Accordingly, this paper presents a study among production and distribution plans with the main aim of identifying gaps in the current optimisation models, taking into account the requirements and needs coming from the specifications defined in the C2NET industrial pilots . Specifically, this paper reports the literature review regarding optimisation models for integrated production-distribution planning decisions. A summary of a review of optimization models for integrated production and delivery planning decisions is presented. In this regard, this paper will provide researchers and practitioners a starting point for generating optimization models in the context of integrated production-distribution planning.

To this regard, the paper is organised as follows: In section 2 a brief description of C2NET project is provided, focusing on the Dermo-cosmetics sector. In Section 3 a review of the combined models for production and distribution planning is provided and the gaps between the literature and the industry are identified. Finally, Section 4 presents the conclusions.

## 2. Dermo-cosmetics pilot in C2NET project

The current research work carries out a state of the art to collect and analyse some solutions in the context of distribution and production planning. This research is part of the C2NET H2020 project (2015-2017) that addresses the potential of Cloud technologies providing a collaboration infrastructure for the real-world data of different supply chain components such as manufacturing assets status, inventory levels or current demand at consumption points (Lauras *et al.*, 2015).

C2NET H2020 project is motivated by the fact that currently, the European SMEs do not have access to advanced management systems and collaborative tools because of their limited resources (European Commission, 2005, 2012, 2013, 2014). Value chains formed by SMEs are distributed and dependent on information and complex materials flows that require new approaches to reduce the complexity of manufacturing management systems. In this context, ubiquitous tools are needed to support collaboration between different entities in the value chain and offer advanced algorithms to achieve global and local optimization of manufacturing processes and respond more quickly and efficiently unforeseen changes. The main objective of C2NET is building a new architecture in the cloud to provide SMEs, affordable tools (in terms of cost and ease of use) to help overcome the current economic crisis, improving competitiveness in the economy world.

Therefore, C2NET objective is based on the creation of cloud tools to support optimization of manufacturing networks composed mainly of SMEs and their logistic assets through demand management, production and supply plans, considering the Collaborative Network perspective (Andres *et al.*, 2016).

C2NET will provide specific tools for optimisation and collaboration in the cloud, allowing enterprises to be responsive and flexible against changes in

both the demand and unexpected events that take place during products production and distribution. Moreover, C2NET will provide a technological infrastructure that allows collecting real-world data from processes and products within the supply chain. Finally C2NET project provides collaboration tools with a set of services able to facilitate the decision-making processes, increasing the enterprises agility.

Accordingly, the C2NET Project will generate a Cloud Architecture composed by the Cloud Platform (C2NET CPL), the Data Collection Framework (C2NET DCF), the Optimizer (C2NET OPT) and the Collaboration Tools (C2NET COT) (see Figure 1).

The validation of C2NET outputs (collaborative platform) will be possible with the four industrial pilots participating in the project. Each pilot is devoted to improve different collaborative levels, due to their characteristics. Thus, pilots corresponding to the automotive sector and OEM manufacturing are devoted to enhance production collaborative processes. The dermo-cosmetics pilot is focused to enhance deliver collaborative processes. The metalworking pilot is devoted to enhance source collaborative processes. This paper focuses on the planning needs of Dermo-cosmetics Pilot regarding production and distribution. The supply chain under study in contains one production unit, its international warehouse, two subsidiaries' distribution centres and 20 retailers (pharmacists' drugstores). In a first stage, the supply chain under study concerns one production unit, his international warehouse, two subsidiaries' distribution centres and 20 retailers (pharmacists' drugstores). In a second phase, this pilot propose to test the scalability at a bigger size, the European supply chain composed of 15 distribution subsidiaries and 50000 selling points.

Enterprises of Dermo-cosmetics pilot will use the C2NET platform (cloud infrastructure) and software to perform collaborative production and distribution network from first-tier suppliers of materials to final resellers all over the world. The use of C2NET optimiser will optimise the availability of products and limiting the inventory levels all along the supply chain. In this pilot the collaboration tools will be used to manage the production and delivery collaborative processes between the manufacturing plant, the subsidiaries, the transportation companies and the retailers. This will particularly take effect on the capability of these stakeholders to better manage the uncertainties such as sudden demand variation or transportation failures. The C2NET platform will improve the agility capabilities of the whole network.

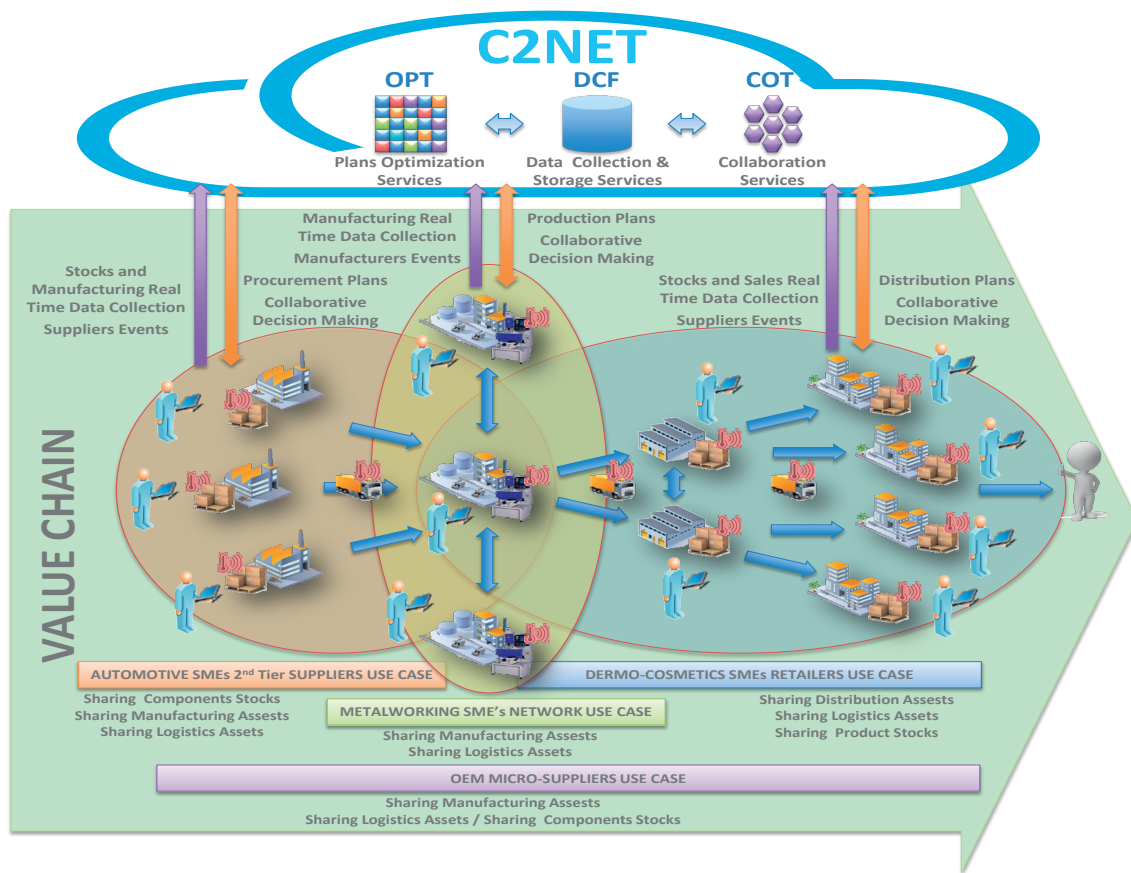


Figure 1. C2NET Project results.

### 3. Integrated optimization models for production-distribution planning

The consideration of a collaborative production and distribution planning problem is a determined decision to improve the net profit in a multi-plant, multi-retailer, multi-item, and multi-period logistic environment. Different optimisation models and heuristic solutions have been proposed in the literature to deal with both integrated and decoupled plans of production and distribution. The main problems to face are the high inventory levels required to cover the demand, the long lead times that freeze a lot of assets, the bullwhip effect, the back orders, changes in short-term forecasts, etc. Next subsections will analyse the current solutions to of distribution plans and solutions that propose optimisation models, algorithms and simulation approaches to deal with the collaborative production and distribution planning.

#### 3.1. Distribution Planning

Distribution planning deals with the Plan Delivery (D) identified in the SCOR views (Supply Chain Council, 2012), and focuses on the calculation of the amount of items to be delivered per periods in a planning horizon. The main input data are the customers' orders, with amounts and locations to deliver the goods. The delivery will use limited resources (own, from the customer or from a third party). Distribution plans can be arranged considering four category levels:

- D/Demand Planning: Plan that enables sales teams to develop demand forecasts as input to the service planning processes, production, inventory planning and revenue planning;
- D/Distribution Planning: Plan that concerns the movement of a finished product or services to the customers. The customer is the final destination of a selling channel. This plan examines demographic characteristics and travel patterns evaluates alternative improvements for the distribution of finished products. Distribution

**Table 1.** Matching Pilot 2 industrial needs and deliver literature plans.

Industry Needs	Input Data								Objectives					Output Data						Algorithm Type
	<i>Id</i> <sub>1</sub>	<i>Id</i> <sub>2</sub>	<i>Id</i> <sub>3</sub>	<i>Id</i> <sub>4</sub>	<i>Id</i> <sub>5</sub>	<i>Id</i> <sub>6</sub>	<i>Id</i> <sub>7</sub>	<i>Id</i> <sub>8</sub>	<i>O</i> <sub>1</sub>	<i>O</i> <sub>2</sub>	<i>O</i> <sub>3</sub>	<i>O</i> <sub>4</sub>	<i>O</i> <sub>5</sub>	<i>Od</i> <sub>1</sub>	<i>Od</i> <sub>2</sub>	<i>Od</i> <sub>3</sub>	<i>Od</i> <sub>4</sub>	<i>Od</i> <sub>5</sub>	<i>Od</i> <sub>6</sub>	
Martin (1995)	X	X					X			X	X			X	X	X		X	AH/ Greedy	
Fliedner (2003).	X		X	X			X						X		X	X			AO/ Dynamic Programming	
Venkatadri <i>et al.</i> (2006)	X	X			X		X	X			X	X		X		X	X		AO/ Simplex	
Gelper <i>et al.</i> (2010)	X											X						X	AO/ Dynamic Programming	
Fildes <i>et al.</i> (2009)	X											X						X	AO/ Dynamic Programming	
Chan <i>et al.</i> (2006)	X		X	X	X		X		X				X	X		X	X	X	AM/ Genetic Alg.	
Arntzen <i>et al.</i> (1995)	X		X	X	X		X				X	X	X		X	X	X	X	AO/ Simplex	
Wang <i>et al.</i> (2011)	X			X			X					X		X	X	X	X		AO/ Branch and Bound	
Florez <i>et al.</i> (2015)	X		X		X		X				X		X	X	X	X	X		AO/ Branch and Bound	
Santoso <i>et al.</i> (2005)	X		X	X	X		X				X		X	X	X	X	X		AH/Decomposition and Aggregation	
Rim <i>et al.</i> (2014)	X	X	X	X			X			X	X			X	X			X	AM/ Genetic Alg.	
Torabia and Hassini (2008)	X	X	X								X								AO/ Fuzzy Programming	
Meijboom and Obel (2007)	X		X	X					X	X			X		X			X	AO/ GAMS	

*Id*<sub>1</sub>: Demand, *Id*<sub>2</sub>: Inventory, *Id*<sub>3</sub>: Capacity, *Id*<sub>4</sub>: Production Time, *Id*<sub>5</sub>: Transport/Distribution Cost, *Id*<sub>6</sub>: Backorders, *Id*<sub>7</sub>: Lead time of supply, *Id*<sub>8</sub>: Supplier Prices.

*O*<sub>1</sub>: Transport cost min, *O*<sub>2</sub>: Sales max, *O*<sub>3</sub>: Inventory min, *O*<sub>4</sub>: Backorders min, *O*<sub>5</sub>: Service Level max.

*Od*<sub>1</sub>: Transport cost, *Od*<sub>2</sub>: Backorders, *Od*<sub>3</sub>: Inventory, *Od*<sub>4</sub>: Delivery time, *Od*<sub>5</sub>: Total cost, *Od*<sub>6</sub>: Product to transport.

planning includes steps like: (i) calculation of distances, times and distribution costs; (ii) optimisation of distribution routes; (iii) analysis of logistic flows; and (iv) design and analysis of a distribution network;

- D/Order Promising: Plan that matches customer orders against available manufacturing resources and then replies with promised quantities and due dates;
- D/Transport Planning: Plan that concerns the movement of raw materials or semielaborated products to manufacturing enterprises. Plan that deals with procurement transport activities for accomplishing production requirements.

Table 1 below presents the mapping between Dermo-cosmetics industrial pilot optimisation needs and plans described in literature. The first column carries the reference of a plan in literature. For any optimisation case the input data, objectives and output data are crucial and need to match sufficiently. Input

data was classified into eight classes, objectives five and output data six. The last column identifies the algorithm type presented in the literature reference: AO is an optimisation algorithm, AH is a heuristic algorithm and AM is a matheuristic algorithm. Each X in the table presents a match between the algorithm in literature and industrial pilot optimisation needs. Correspondingly, each empty cell identifies a gap between literature and real case.

### 3.2. Collaborative Production and Distribution Planning

Make & Deliver (MD) plans deal with the transformation of a product into a finished good and provide finished goods and services to meet planned or actual demands. Dermo-cosmetics pilot allowed defining two collaborative processes regarding MD plans:

- M/Production Planning & D/Distribution Planning: Plan that deals with production and

distribution operations to customers, over the planning horizon. The plan identifies the production and distribution quantities of each item for each period at each site, subject to consider the capacity constraints and distribution lead-time. The total cost includes the costs of production, inventory, stockout, and distribution;

- M/Production Planning & D/Transport Planning: Plan that deals with two phases, (i) the manufacturing phase that focuses on the efficient allocation of the production capacity at the various production sites, and (ii) the transportation phase that focuses on procurement transport activities for accomplishing production requirements.

Table 2 identifies the matches between the Dermo-cosmetics industrial pilot optimization needs and combined collaborative MD planning algorithms found in literature. This table follows the same structure as Table 1 in section Distribution planning.

### 4. Conclusions

The research work carried out in this paper identifies the concrete solutions proposed in the literature to support the collaborative process of production and distribution planning. The literature plans are compared with the real requirements collected from the industry. In this regard, the needs of one of the pilots of C2NET project, the Dermo-cosmetics pilot, are analysed. The comparison allowed identifying some gaps between the literature and the industrial needs regarding collaborative production and distribution planning. The algorithms found in the literature will need massive modifications before they can be applied in the optimisation cases because both the amount and nature of inputs, objectives and outputs have very low correlation with the industry needs. Some features of solutions found in literature will be adapted when implementing collaborative

**Table 2.** Matching Pilot 2 industrial needs and integrated production-distribution literature plans.

Industry Needs	Input Data								Objectives					Output Data						Algorithm Type
	$Id_1$	$Id_2$	$Id_3$	$Id_4$	$Id_5$	$Id_6$	$Id_7$	$Id_8$	$O_1$	$O_2$	$O_3$	$O_4$	$O_5$	$Od_1$	$Od_2$	$Od_3$	$Od_4$	$Od_5$	$Od_6$	
Park (2005)	X		X	X	X	X		X										X		AO/ Simplex
Jung and Jeong (2005)	X			X	X		X		X		X	X		X	X	X				Colaborative Agents
Jang <i>et al.</i> (2002)	X		X	X			X				X	X		X	X				X	Heuristic
Gupta and Maranas (2003)	X	X	X								X									AM/ Genetic Alg.
Eksioglu <i>et al.</i> (2006)	X		X	X					X		X			X		X			X	AH/ Primal-Dual
Chen and Wang (1997)	X		X	X	X			X												AO/ Simplex
Dhaenens and Finke (2001)		X	X	X					X											AO/ Simplex
Jayaraman and Pirkul (2001)	X	X	X		X				X										X	AH/Lagrangian
Sakawa <i>et al.</i> (2001)	X		X		X				X										X	AO/ Simplex
Lee and Kim (2002)			X		X				X		X								X	AO/ GAMS
Selim <i>et al.</i> (2008)	X		X		X							X				X			X	AO/ Simplex
Aliev <i>et al.</i> (2007)	X				X														X	AM/ Genetic Alg.
Rizk <i>et al.</i> (2006)	X	X			X				X							X			X	AO/ Simplex

$Id_1$ : Demand,  $Id_2$ : Inventory,  $Id_3$ : Capacity,  $Id_4$ : Production Time,  $Id_5$ : Transport/Distribution Cost,  $Id_6$ : Backorders,  $Id_7$ : Lead time of supply,  $Id_8$ : Supplier Prices.

$O_1$ : Transport cost min,  $O_2$ : Sales max,  $O_3$ : Inventory min,  $O_4$ : Backorders min,  $O_5$ : Service Level max.

$Od_1$ : Transport cost,  $Od_2$ : Backorders,  $Od_3$ : Inventory,  $Od_4$ : Delivery time,  $Od_5$ : Total cost,  $Od_6$ : Product to transport.

optimization algorithms for the requirements defined by the industry.

### Acknowledgements

The research leading to these results is in the frame of

the “Cloud Collaborative Manufacturing Networks” (C2NET) project, which has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 636909.

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