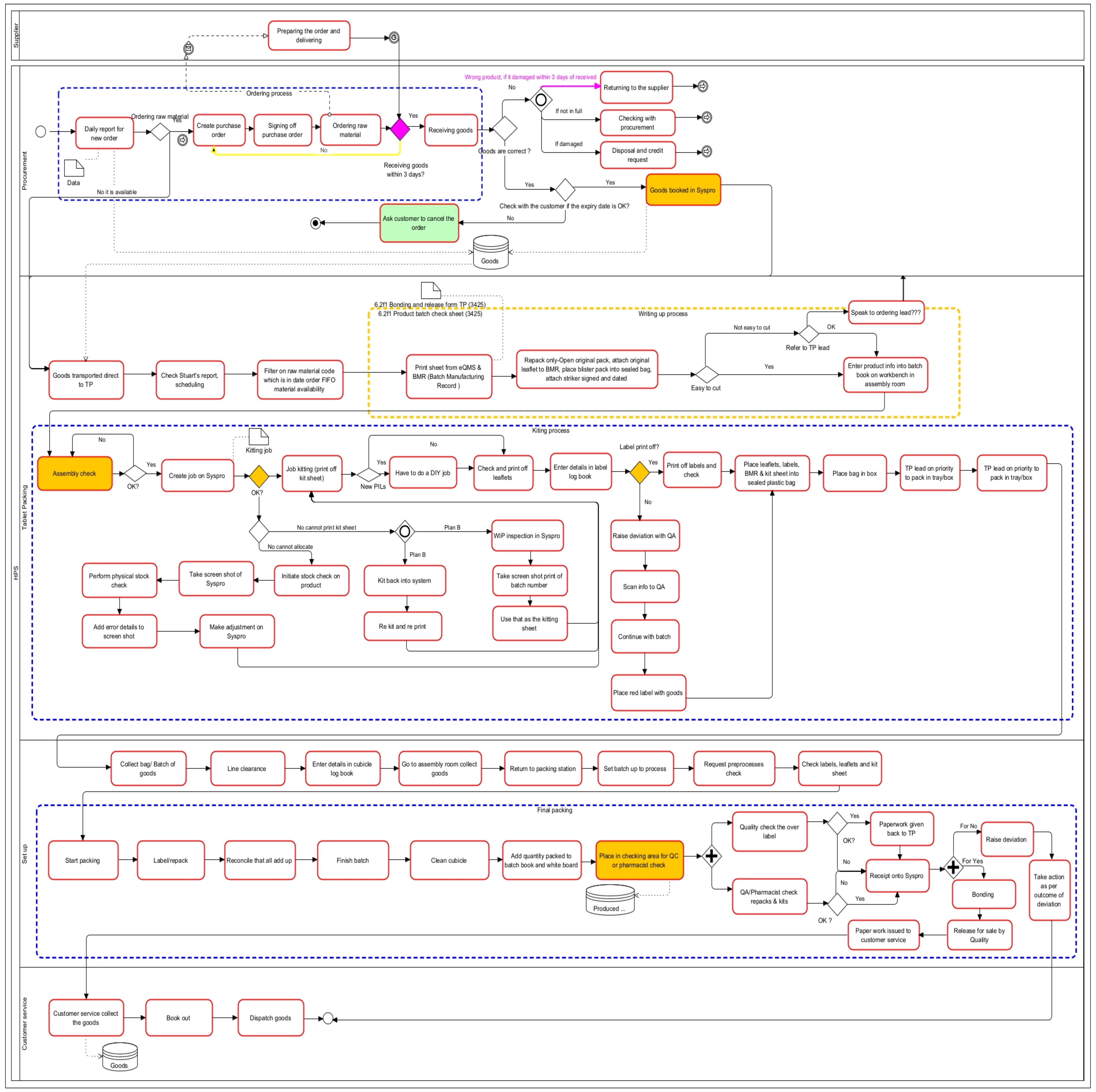
Production and logistics synchronisation for smart pharmaceutical manufacturing

Daqiang Guo
Centre for International Manufacturing, Institute for Manufacturing (IfM),
Department of Engineering, University of Cambridge, Cambridge, United Kingdom
Email: dg654@cam.ac.uk

Use case: Huddersfield Pharmacy Specials (HPS)



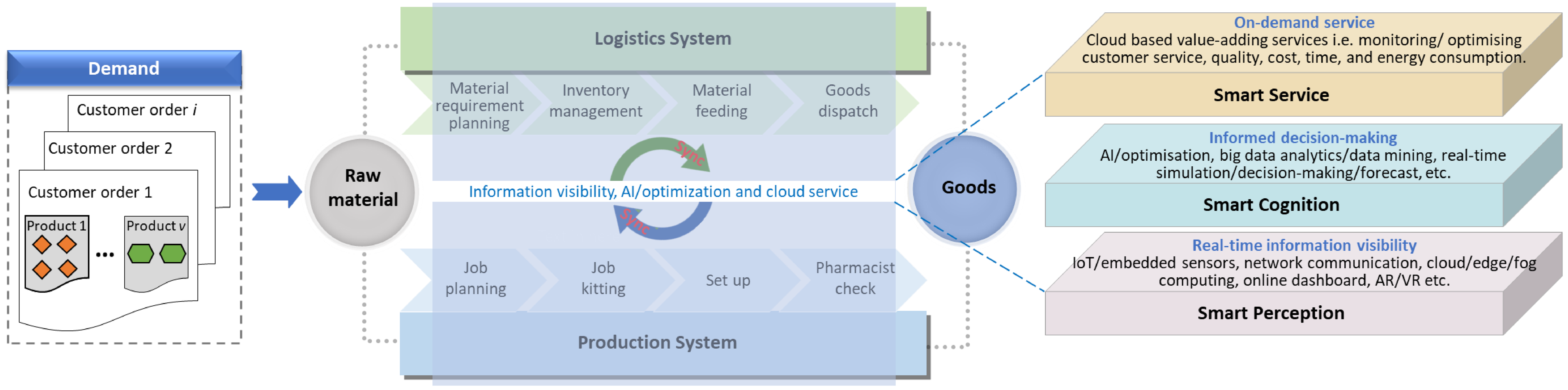
Business process model and notation (BPMN) for HPS tablet packing (TP) process

The problems caused by unsynchronised production system (process flow) and logistics system (material flow):

- ***Unnecessary operations*** e.g. duplication of checks across different functions (6 checks being performed in TP checks), and frequent setup operations
- ***Long waiting/lead time*** e.g. delayed TP kitting due to untimely raw material of child component feeding
- ***Inventory problem*** e.g. stockout due to outdated material requirements planning, uncoordinated TP kitting process within the same order leads to high finished product inventory level

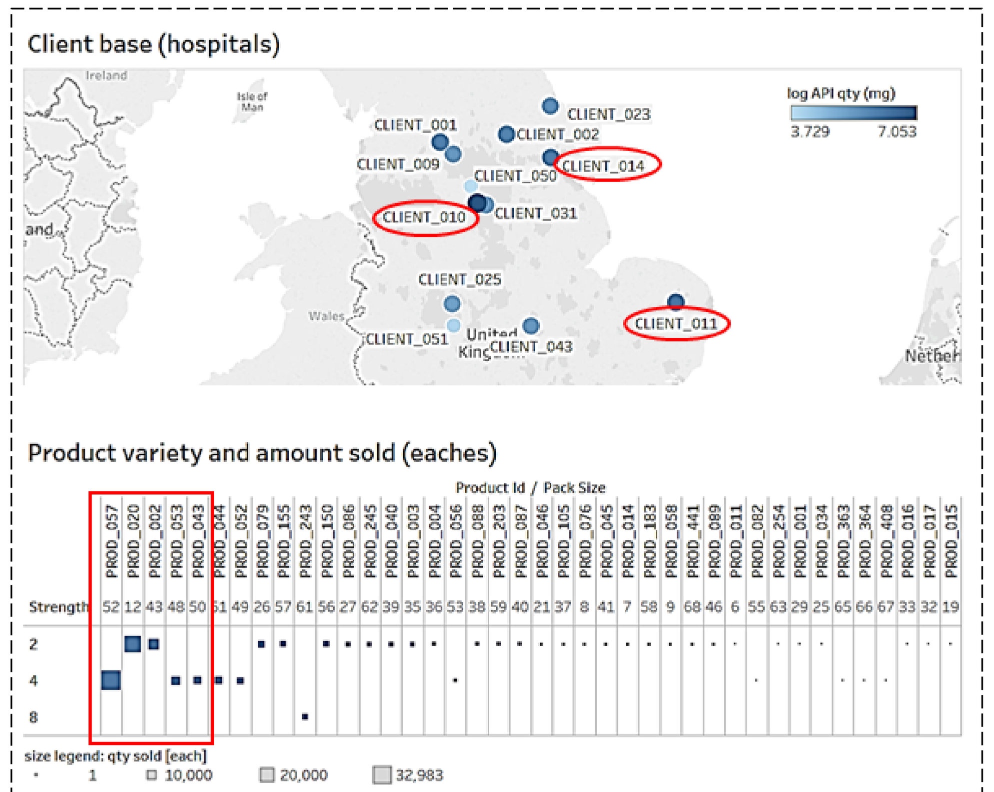
Research idea: smart production and logistics synchronisation

- Real-world demand signal-driven
- Cut unnecessary operations, shorten lead time, reduce waste and enhance sustainability
- Leverage real-time information flow, informed coordinated decision-making and cloud service



Research findings for HPS TP process

- The future state-synchronisation strategy results in an average cutting of 31.02% in lead time in the production system and 54.20% in the logistics system compared to the current state
- The future state-synchronisation strategy results in an average reduction of 34.41% in total energy consumption
- The more severe the logistics delay, the greater the advantages brought by the future state-synchronisation strategy

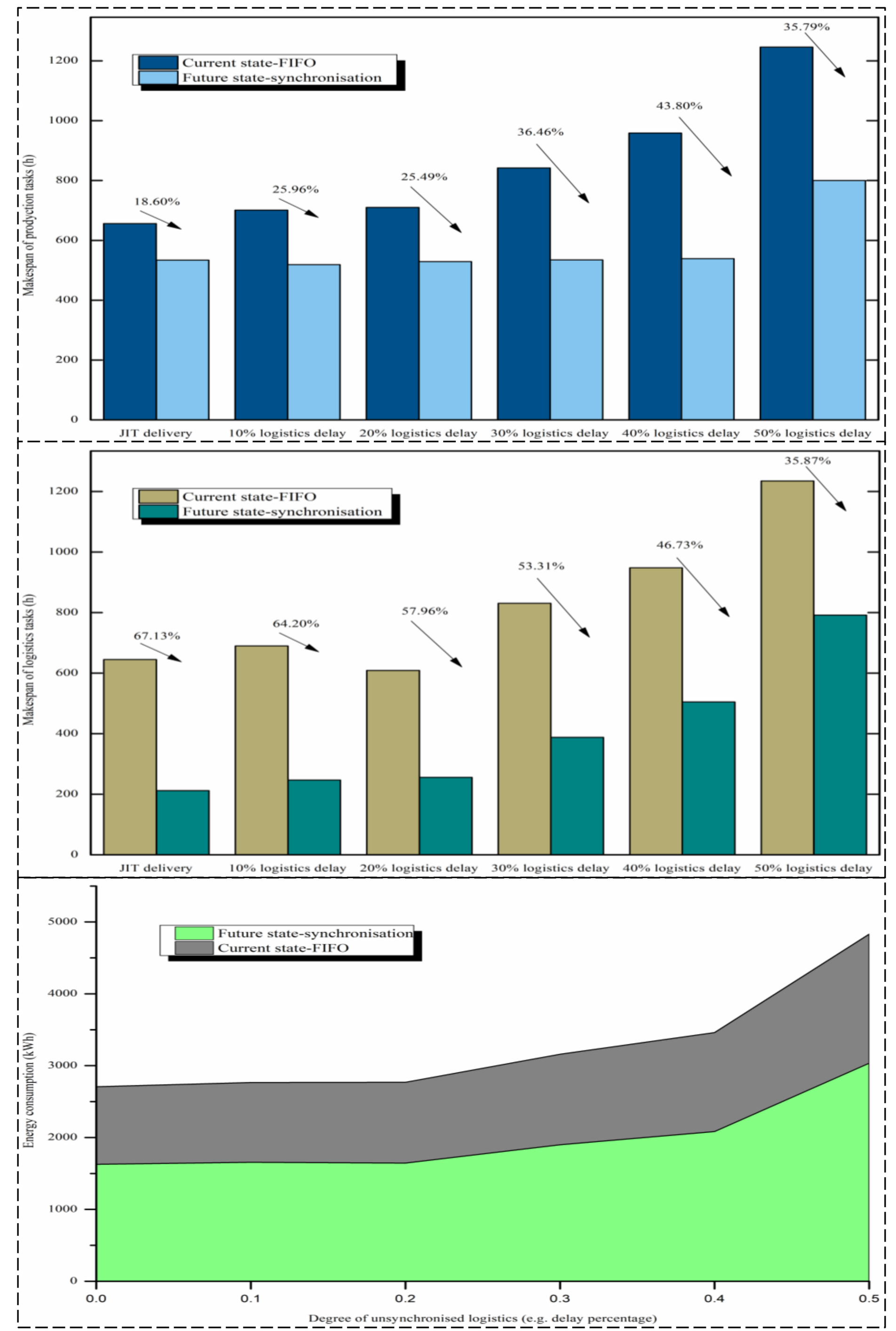


Customer order	Product ID	Strength	Pack size	Quantity
CLIENT_010_20190103	PROD_057	4mg	52	1,000
	PROD_020	2mg	12	500
	PROD_002	2mg	43	300
CLIENT_011_20190105	PROD_020	2mg	12	600
	PROD_043	4mg	50	300
CLIENT_014_20190107	PROD_057	4mg	52	500
	PROD_053	4mg	48	300
	PROD_043	4mg	50	200
	PROD_002	2mg	43	200

Real-world demand signal

$$\text{Minimize } (C_P^t + C_L^t)$$
$$C_P^t = \text{Max}(PS_m^e(F_{fc}^u))$$
$$C_L^t = \text{Max}(LS_n^e(F_{fc}^u))$$
$$\sum_{m=1}^{m_t} x^{PS_m}(F_{fc}^u) = 1, \forall u, f, c$$
$$PS_m^e(F_{fc}^u) - PS_m^s(F_{fc}^u) \geq PS_m^f + M\left[x^{PS_m}(F_{fc}^u) - 1\right], \forall m, u, f, c$$
$$M\left[xx^{PS_m}(F_{fc}^u, (F_{fc}^u)') + x^{PS_m}(F_{fc}^u) + x^{PS_m}((F_{fc}^u)') - 3\right]$$
$$\leq PS_m^s((F_{fc}^u)') - PS_m^e(F_{fc}^u) - S_{ff'}, \forall m, u, f, c$$
$$M\left[x^{PS_m}(F_{fc}^u) + x^{PS_m}((F_{fc}^u)') - xx^{PS_m}(F_{fc}^u, (F_{fc}^u)') - 2\right]$$
$$\leq PS_m^s(F_{fc}^u) - PS_m^e((F_{fc}^u)'), \forall m, u, f, c$$
$$PS_m^s(F_{fc}^u) \geq t + S_f, \forall m, u, f, c$$
$$PS_m^e(F_{fc}^u) \leq T_d^c, \forall m, u, f, c$$
$$\sum_{n=1}^{n_t} x^{LS_n}(F_{fc}^u) = 1, \forall u, f, c$$
$$LS_n^e(F_{fc}^u) - LS_n^s(F_{fc}^u) \geq LS_n^f + M\left[y^{LS_n}(F_{fc}^u) - 1\right], \forall n, u, f, c$$
$$M\left[yy^{LS_n}(F_{fc}^u, (F_{fc}^u)') + y^{LS_n}(F_{fc}^u) + y^{LS_n}((F_{fc}^u)') - 3\right]$$
$$\leq LS_n^s((F_{fc}^u)') - LS_n^e(F_{fc}^u), \forall n, u, f, c$$
$$M\left[y^{LS_n}(F_{fc}^u) + y^{LS_n}((F_{fc}^u)') - yy^{LS_n}(F_{fc}^u, (F_{fc}^u)') - 2\right]$$
$$\leq LS_n^s(F_{fc}^u) - LS_n^e((F_{fc}^u)'), \forall n, u, f, c$$
$$x^{PS_m}(F_{fc}^u) \in \{0,1\}, \forall m, u, f, c$$
$$y^{LS_n}(F_{fc}^u) \in \{0,1\}, \forall n, u, f, c$$
$$xx^{PS_m}(F_{fc}^u, (F_{fc}^u)') \in \{0,1\}, \forall m, u, f, c$$
$$yy^{LS_n}(F_{fc}^u, (F_{fc}^u)') \in \{0,1\}, \forall n, u, f, c$$
$$PS_m^s(F_{fc}^u) - LS_n^e(F_{fc}^u) \geq 0, \forall m, n, u, f, c$$

Informed coordinated decision-making model



Simulation results

Acknowledgment: The authors would like to thank the Digital Medicines Manufacturing (DM²) Research Centre (Grant Ref: EP/V062077/1) for funding this work. DM² is co-funded by the Made Smarter Innovation challenge at UK Research and Innovation and partner organisations from the medicines manufacturing sector. For more information, visit cmac.ac.uk/dm2-home

UK Research and Innovation

MADE SMARTER INNOVATION

DM² Digital Medicines Manufacturing