MSIE 4.0

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II. Machines Collaboration on a Shop Floor

Distributed Manufacturing

Curriculum Development
of Master's Degree Program in
Industrial Engineering for Thailand Sustainable Smart Industry

Distributed manufacturing

Distributed manufacturing also known as **distributed production**, **cloud producing** and **local manufacturing** is a form of decentralized manufacturing practiced by enterprises using a network of geographically dispersed manufacturing facilities that are coordinated using information technology.

Distributed Manufacturing Model

The distributed manufacturing model dismisses location to find the best talent. The network allows for a specialist factory to fill excess capacity, whilst keeping manufacturing local to the products final destination, reducing emissions and logistics cost all while also keeping quality of product for the end consumer. It's a very agile model that allows for quick and scalable movement in modern business.

Source: https://cerasis.com/distributed-manufacturing/

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The Rise of Distributed Manufacturing

7 Advantages over Traditional Manufacturing

1. By manufacturing items closer to their end destination, logistics cost, time from production to sale and environmental impact are reduced.

2. By leveraging the expertise of a larger remote network, limitations like location and the cost of full time employees are eliminated.

3. Without permanent investment in facilities, the manufacturing supply chain is made more agile. A company must be able to expand and contract their infrastructure at lightning speeds to stay competitive and survive economic waves.

4. It is possible to distribute workloads across multiple suppliers. Reducing risk of a failure on production line.

5. Manufacturers are also able to support multiple smaller economies by distributing their factories. If aiming to sell in a location, it makes both financial and moral sense to support the local economy.

6. Outsourcing to multiple smaller facilities allows you to make use of existing experts. Many larger production lines will develop in house techniques, but this takes significant time and investment.

7. By opening up your supply chain to a network, can make use of excess capacity.

Source: https://cerasis.com/distributed-manufacturing/

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Distributed Manufacturing: scope, challenges and opportunities

- **Distributed Manufacturing (DM)** include a range of technologies that are becoming progressively mature, such as
  - Sensors and process analytics that may provide enhanced production control
  - Information and communication technologies (ICT) that support supply chain integration utilizing
  - Data analytics that can provide insights both from raw data and also embedded data on multiple machine/equipment/product objects (IOT)

- **DM** are not only key elements of *smart manufacturing, intelligent and autonomous system, digitalization and smart machines*, but also new societal considerations of a highly participative form of *decentralized manufacturing*, where participation extends right through to the end-user, and across the manufacturing value chain, i.e., from design to potentially production.

- **DM** is particularly characterized by technological developments in engineering and computing that bring new capabilities to manufacturing in terms of automation, complexity, flexibility and efficiency.

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(Srai et al., 2016)

Distributed Manufacturing: scope, challenges and opportunities

Case example of DM: **3D Printing (Simon Ford)**

3D printing technology is becoming increasingly popular at end-user level. As the performance of consumer 3D printing improves, there may be convergence between consumer 3D printing networks such as 3D Hubs and inter-organisational industrial 3D printing networks.

Cases	Context	Characteristics of DM	Opportunities and Challenges			
			Enabling production technologies and Infrastructure	Governance and regulatory	Resilience and sustainability	Transformation
1	3D printing	▪ Production when needed and closer to point of consumption ▪ Integrated product ▪ Direct digital Manufacturing – rapid prototyping and tooling ▪ Economically viable, customized product on demand	▪ Two-sided platform linking customers wanting to access 3D printing capability with owners of 3D printers ▪ Software that enable 3D printing files to be created, modified and distributed ▪ Low cost of 3D printing equipment and materials ▪ CAD skills required to create designs.	▪ Standards, compatibility, regulation and certification ▪ Ownership issues	▪ Sustainability benefits across the product and material life cycles ▪ Business model uncertainty ▪ Material supply chain issues ▪ Current performance limitations including the quality, limited range of materials and functionality	▪ Convergence between consumer 3D printing networks and inter-organisational industrial 3D printing networks ▪ Ability of organizations to create and capture value ▪ Ambiguity about economic and environmental impacts ▪ Uncertainty and ambiguity regarding how governance structures will emerge and evolve

(Srai et al., 2016)

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Distributed Manufacturing: scope, challenges and opportunities

Case example of DM: **Consumer Goods and Connected Manufacturing (Ashutosh Tiwari)**

DM enables a more connected, localized and inclusive model of consumer goods production and consumption that is driven by the exponential growth and embedded value of big data

The integration of distributed knowledge, production, distribution and technologically driven manufacture enables:

- Connected more meaningful and durable relationships with the end user
- Automated monitoring, control and optimization of stock and material flows
- User-driven design of customized goods and services at a local scale through connected supply chains and on-demand production
- Mass customization and bespoke fabrication
- Open Source Innovation and Distributed Retailing

Cases	Context	Characteristics of DM	Opportunities and Challenges			
			Enabling production technologies and Infrastructure	Governance and regulatory	Resilience and sustainability	Transformation
3	Consumer Goods and Connected Manufacturing	▪ Opportunity for personalization ▪ Up scaling of local enterprise ▪ Development of user-driven products that are tuned to the requirements of local markets ▪ Automated monitoring, control and optimization of stock and material flows ▪ Mass customization and bespoke fabrication	▪ Data integration and analytics ▪ New technical skills are required for such as data analytics and visualization ▪ Incentivizing take-back and reward schemes for more durable consumer goods ▪ User-driven design of customized goods and services at a local scale through connected supply chains and on-demand production ▪ Open Source Innovation Distributed Retailing	▪ Business-to-business and business to consumer data sharing, governance, ownership and security	▪ Opportunities for closed-loop production and consumption ▪ Re-capturing valuable materials ▪ Optimization of manufacturing processes and logistical operations ▪ Opportunities for businesses to share data, engage in data-driven open innovation and create radically distinctive business models	▪ Challenge to up-scale whilst retaining the value ▪ Connected, localized and inclusive model of consumer goods production and consumption that is driven by the exponential growth and embedded value of big data. ▪ Connected, more meaningful and durable relationships with the end user ▪ Monitoring, control and optimization of stocks and material flows

(Srai et al., 2016)

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Distributed Manufacturing: scope, challenges and opportunities

5 characteristics of DM cross case study: *digitalization, personalization, localization, new enabling technologies, and enhanced user and producer participation*

DM characteristics	Case 1 3D Printing	Case 2 Healthcare	Case 3 Consumer Goods and Connected Manufacturing	Case 4 Community based production	Case 5 Smart City Production System – 3D Weaving	Case 6 Pharmaceutical Case study
Digitalization	Rapid prototyping, tooling. Direct digital manufacture.	Develop small, automated or semi-automated units capable of producing the therapies from, for example, kits provided by the OEM.	Automated monitoring, control and optimization of stock and material flows. Open Source Innovation Distributed Retailing.	Digital networks. Platform based approach transports data not materials, taking advantage of the growing ad hoc infrastructure of open access workshops and globally standard protocols.	Cooperation and communication over processes and networks in order to achieve the optimum localized manufacturing output (per day) to meet city demand.	Digital factories, smart packaging, and sensors. Medical devices.

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(Srai et al., 2016)

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Personalization	Allows new design freedoms, rapid prototyping. Lot size down to one (job shop production at economic cost), where required.	Exploit the patient-specific characteristics of ACBT products.	Mass customization and bespoke fabrication.	Proximity to and interaction with the maker will give customers the ability to be involved in the production and customization process as well as being a (relatively) cost effective means to have bespoke items made for them.	Made to order due to production being near to market or individual customer, allows co-creation in product development.	Emergence of personalized and stratified medicines.

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(Srai et al., 2016)

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Localization	Manufacture of economically viable customized products on-demand.	Through DM, ACBTs could be produced at or near the point of care.	Radically different model of consumer goods production, purchase and use. Increased resilience. Closed-loop production and consumption.	Decentralized and geographically independent distributed production. Open access workshops.	Re-shoring and repatriation of textile manufacturing. Close proximity of manufacturing to urban customers.	Intervention in local spaces – pharmacy, clinics, hospitals, home.

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(Srai et al., 2016)

Distributed Manufacturing: scope, challenges and opportunities

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DM characteristics	Case 1 3D Printing	Case 2 Healthcare	Case 3 Consumer Goods and Connected Manufacturing	Case 4 Community based production	Case 5 Smart City Production System – 3D Weaving	Case 6 Pharmaceutical Case study
New production technologies	3D printing (additive manufacturing).	Automated manufacturing and delivery processes coordinated within the clinical setting.	Optimization of manufacturing processes.	Digital fabrication. Physical products can increasingly be treated as information products.	3D weaving, e.g., to improve the woven structures of their luxury wool fabrics.	Micro-reactors and continuous manufacture providing high variety, low volume.
Multi-user participation	Democratizes manufacturing through presumption.	Multiple healthcare professionals involved in therapy selection and delivery.	User-driven design of customized goods and services at a local scale through connected supply chains and on-demand production.	Community based production system - new generation of designers, makers and tinkerers.	Strong co-creation and sharing components with public space manufacturing capacity.	GPs, clinics, manufacturers, patient (compliance), regulators (technology process approval).

(Srai et al., 2016)

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Distributed Manufacturing: scope, challenges and opportunities

Comparison of other new manufacturing paradigms with DM

	Personalization	Digitization	Localization	New production technologies	Multi-user participation
Virtual Enterprise	No	Yes	Partly	Implied	No
Industry 4.0	Possible, but not at the individual level	Yes	No	Yes	Partly, but not end user
Grid Manufacturing	No	Yes	Partly	Implied	No
Concurrent Engineering	No	Possible	No	New	Partly, but not end user
Cloud based manufacturing	No	Yes	Partly	Implied	No
Smart manufacturing	Possible, but not at the individual level	Yes	No	Yes	Autonomous manufacturing, but does not involve end user
Distributed Manufacturing	Yes	Yes	Yes	Yes	Yes

(Srai et al., 2016)

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Distributed Manufacturing (DM) application strategy

Developing distributed manufacturing strategies from the perspective of a product-process matrix (Kumar et al., 2020)

DM application strategy

DM concept allows companies to achieve flexibility in manufacturing while providing personalised products in short lead times; however, it is challenging for companies to transit from traditional, batch manufacturing to smaller, more agile and distributed operations units.

Strategies are devised to address digital manufacturing transformation challenge:

1. Small-scale distributed manufacturing: the manufacturing of moderate volume products in multiple locations while contemporarily providing mass customization.

↓

This strategy involves the production large volumes of stock keeping units centrally and small-scale customized production near to consumption.

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Distributed Manufacturing (DM) application strategy

Developing distributed manufacturing strategies from the perspective of a product-process matrix (Kumar et al., 2020)

Strategies are devised to address digital manufacturing transformation challenge:

2. In-house decoupled manufacturing: it aims at achieving economies-of scale for primary manufacturing operations while attaining personalization nearer to the consumer.

↓

This manufacturing strategy is capital intensive for the focal firm.

3. Outsourced decoupled manufacturing: it is characterised by the outsourcing of primary manufacturing processes to suppliers while providing personalised products closer to the consumers.

Both in-house and outsourced decoupled manufacturing strategies mainly deal with decoupling of manufacturing processes and moving the end-processes near to the consumption.

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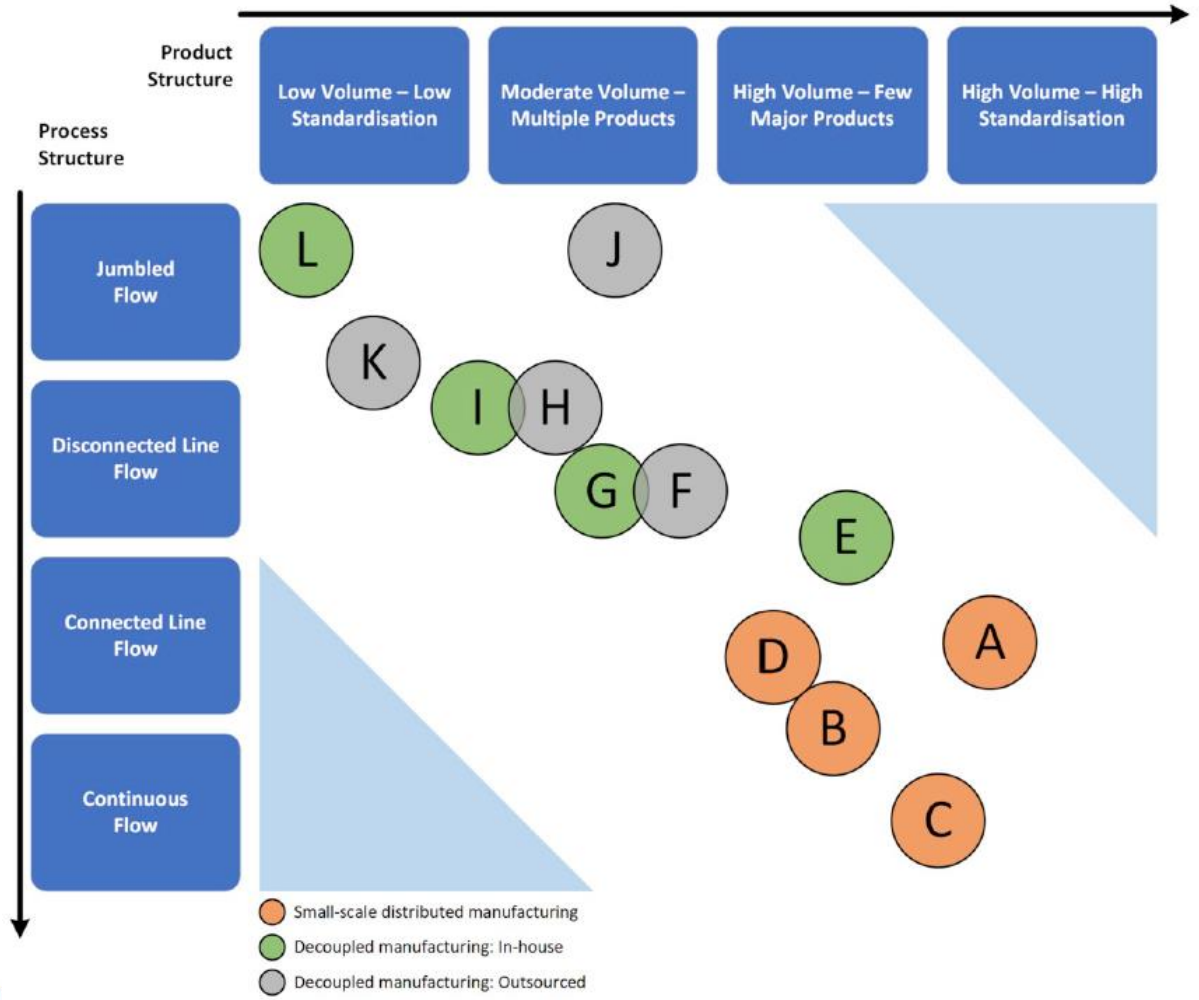
Distributed Manufacturing (DM) application strategy

Developing distributed manufacturing strategies from the perspective of a product-process matrix (Kumar et al., 2020)

Mapping DM application strategies to companies

The mapping approaches of the current status along with the expected transition in future manufacturing scenarios were generated based on the direct input of the informants representing each company/industry.



Note: A – L are 12 multinational companies form Fast-Moving Consumer Goods, Automotive, and Engineering industries

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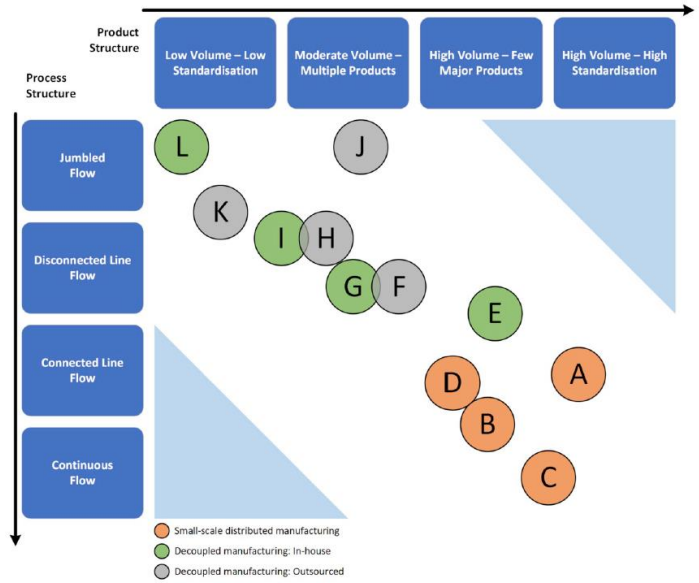

Commodity products in the fast-moving consumer goods (FMCG) industry (i.e. companies A, B, C, D) would be ideal for implementing the small-scale distributed manufacturing strategy in order to reduce the lead time and offer localized customization.

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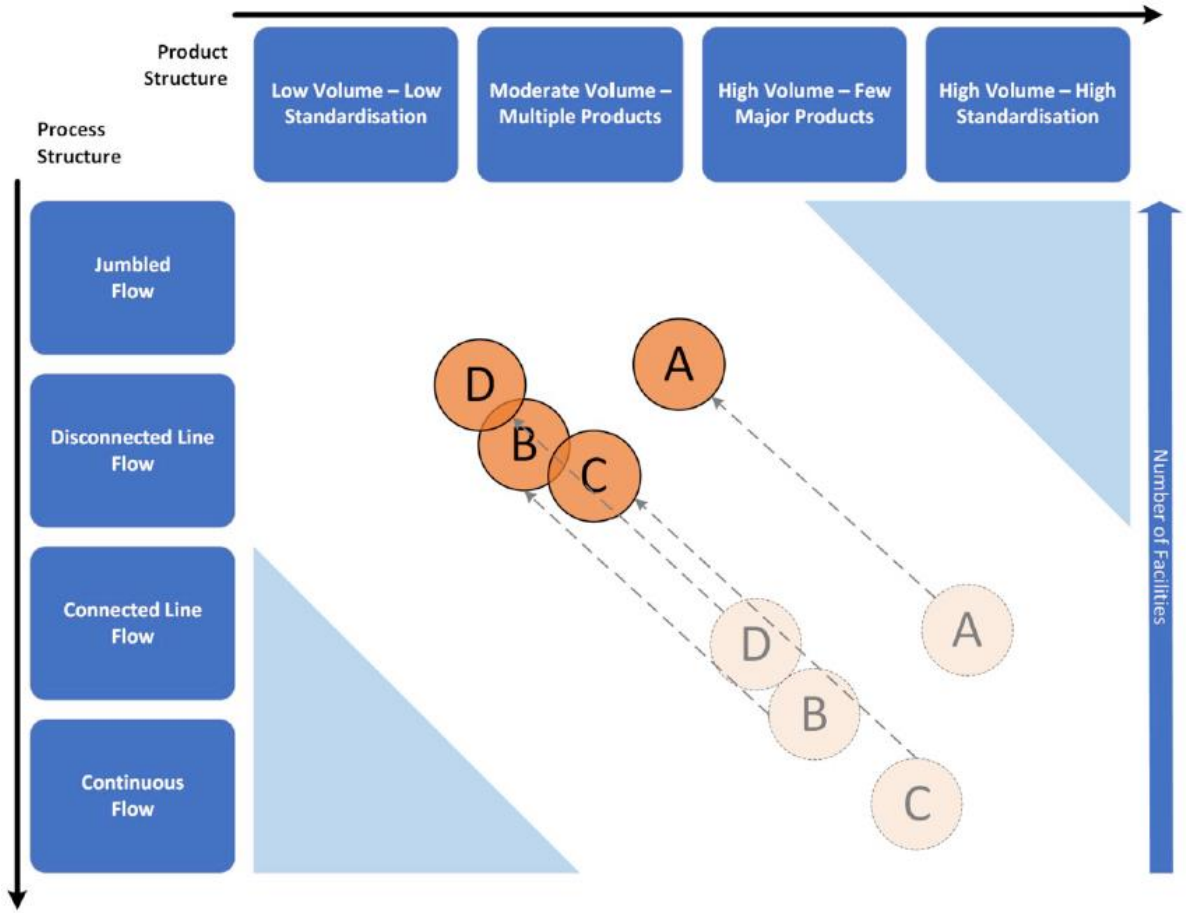
Small-scale distributed manufacturing



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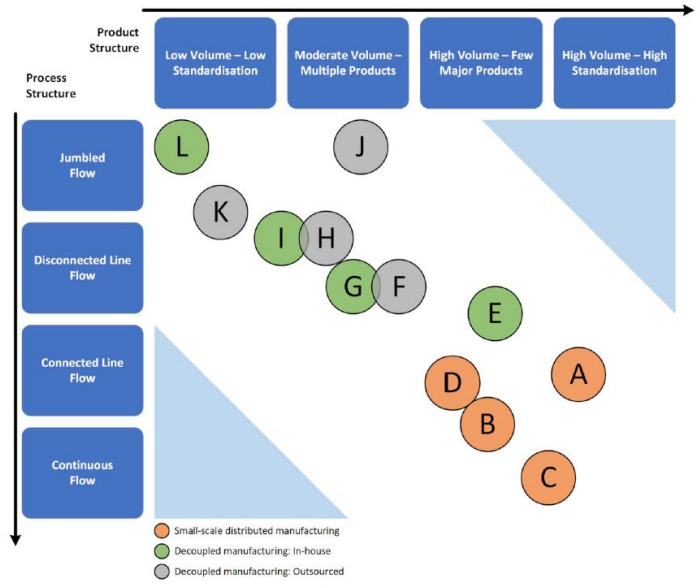
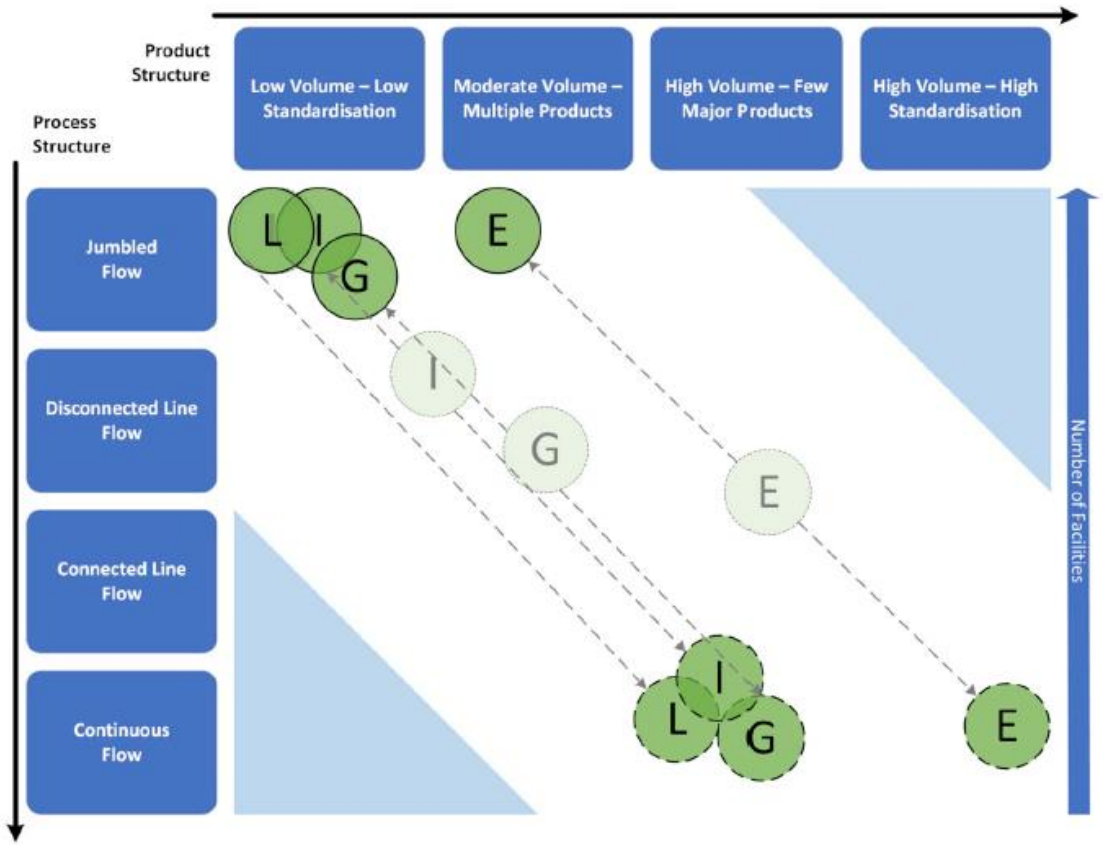


Decoupled manufacturing: In-house



Decoupling the manufacturing operations would allow companies to achieve economies-of-scale for primary operations while attaining personalisation nearer to consumers (i.e. companies E, G, L, I).

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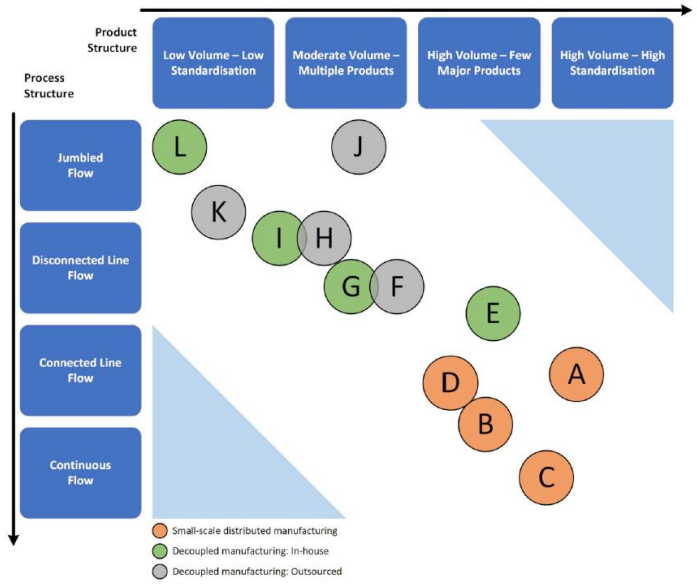
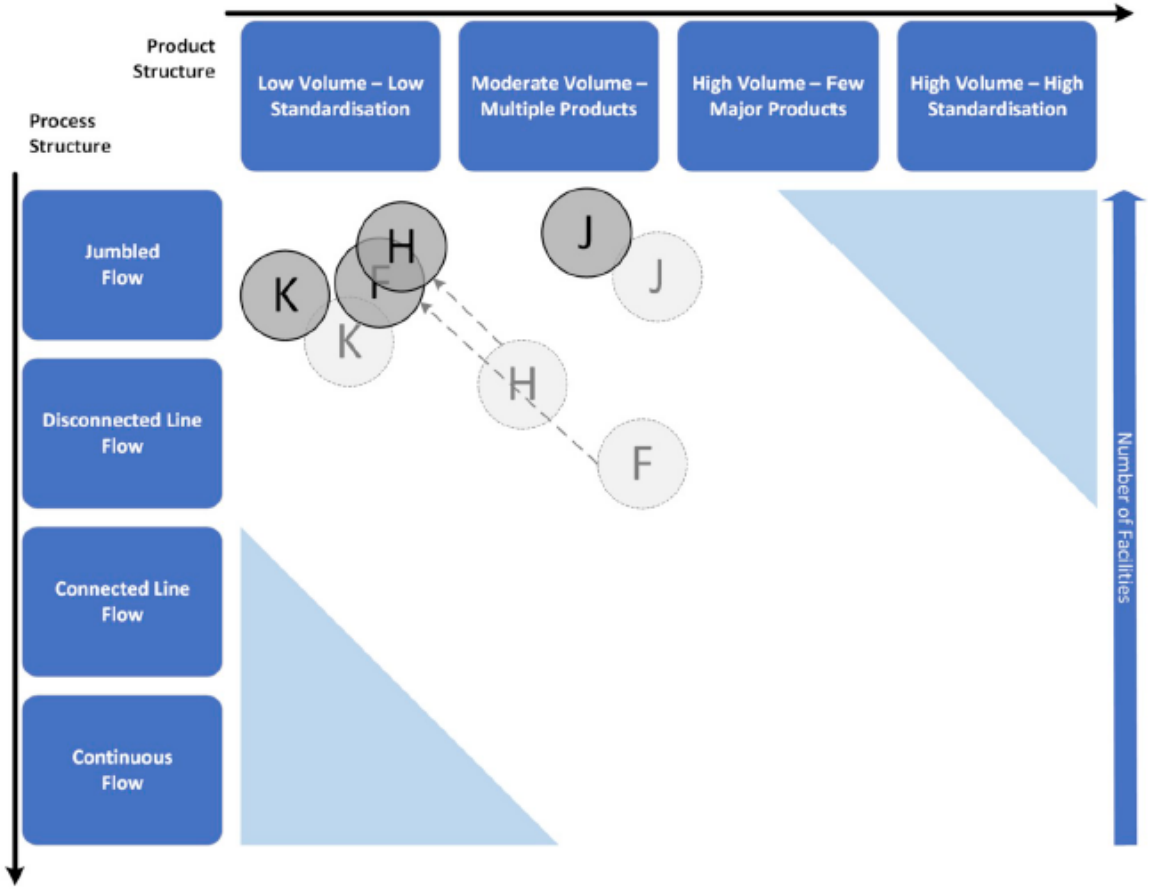


Decoupled manufacturing: Outsourced



Decoupled manufacturing would be suitable for companies willing to outsource manufacturing operations (i.e. companies F, H, J, K), provided that the suppliers are willing to deliver the components to a distributed network of low volume manufacturing facilities.

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Key References

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- M. Kumar, N. Tsolakis, A. Agarwal and J.S. Srai (2020) Developing distributed manufacturing strategies from the perspective of a product-process matrix, International Journal of Production Economics, Vol 219, p. 1-17
- J.S. Srai, M. Kumar, G. Graham, and A. Tiwari (2016) Distributed Manufacturing: scope, challenges and opportunities, International Journal of Production Research

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