

DIGITAL MANUFACTURING ON A SHOESTRING

Low-Cost Digital Solutions for Manufacturing SMEs:
A Catalogue of Digital Solution Areas



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Executive Summary

The aim of this paper is to present a catalogue comprising a set of digital solution areas associated with operational challenges that are relevant to a majority of manufacturing small to medium sized enterprises (SMEs). The working catalogue has been developed in consultation with over 100 manufacturing SMEs. The working catalogue describes 59 solution areas identified to the end of 2020. Out of all participants in the study, 86% ranked one of the top 5 items in the catalogue as a key priority for their business. These findings can help increase accessibility to digitalisation for manufacturing SMEs.

CONTENTS

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1. Introduction
 2. A Working Catalogue of Digital Solution Areas for SME Manufacturers
 - 2.1 Overview
 - 2.2 Developing the Catalogue
 - 2.3 The Catalogue of Digital Solution Areas for Manufacturing SMEs
 3. Interpreting the Working Catalogue
 - 3.1 Catalogue Composition
 - 3.2 The Catalogue and SMEs
 - 3.2.1 The Catalogue and Business Areas
 - 3.2.2 The Catalogue and Manufacturing Operations
 4. Summary
 5. References

1. Introduction

The work reported here is part of the Digital Manufacturing on a Shoestring programme which focusses on low-cost digital solutions for manufacturing SMEs.

The digitalisation of manufacturing processes has the potential to have a profound impact on the manufacturing industry. It can lead to increased efficiency, improved product quality, higher capacity, and many other benefits [1,2]. We define digital manufacturing as *the application of digital information from multiple sources, formats, and owners for the enhancement of manufacturing processes, value chains, products, and services*.

Small and medium sized enterprises (SMEs) face bigger digitalisation challenges than larger companies [3]. However, SMEs represent a large part of the economy.

In the UK manufacturing sector, they accounted for 45% of the economic contribution and employed 53% of the workers in 2019 [4,5]. Two challenges, which are specifically pronounced for SMEs, are the perceived high cost and complexity of digital solutions [6,7]. Despite the high relevance, little research into addressing SME-specific barriers has been conducted to date [8,9]. We use the term SME in accordance with the guidelines of the European Commission, referring to companies with a headcount of <250 and an annual turnover of ≤50MN € [10].

The aim of this study is to identify common digital manufacturing needs of SMEs. The rationale is to provide direction for research into SME digitalisation and to facilitate standardised development of digital solutions to lower the cost barrier of digitalisation.

2. A Working Catalogue of Digital Solution Areas for SME Manufacturers

A key element to supporting digital adoption in SMEs is to identify the operational areas most in need of solutions. This section outlines the approach to developing a catalogue of such digital solution areas. After an overview of the idea and underlying premises, the method used for developing the catalogue is described, and then the working catalogue is presented, and its composition discussed.

2.1. Overview

The catalogue identifies *Digital Solution Areas*. A solution in this context is a system that facilitates a (current or new) activity in a company. A digital solution is then a system that provides this solution by using digital technologies. A solution area describes the purpose of a solution, without referring to a concrete technological implementation. New technologies are developing at a fast pace and the catalogue is intended to be of long-term relevance. The same solution area could be implemented from entirely different technologies in the future. This technology-agnostic

definition of the solution areas makes it easy for SMEs to use the catalogue, as no deep understanding of technology is required.

2.2. Developing the Catalogue

For the development of the working catalogue, we assumed that all types of digital solutions that are currently relevant to SMEs have been deployed before. We used direct feedback from SMEs, case studies, and consultancy reports where the cases were conducted in manufacturing SMEs to identify relevant solution areas.

To combine the different input sources, we followed an iterative process research approach as first proposed by K.W. Platts [11]. The approach consists of multiple research cycles (see Figure 1), after which new solution areas are added to the dynamic catalogue, and then used as input for the next cycle. After sufficient research activity, if no new solution areas can be identified, this is counted as evidence towards the comprehensiveness of the working catalogue.

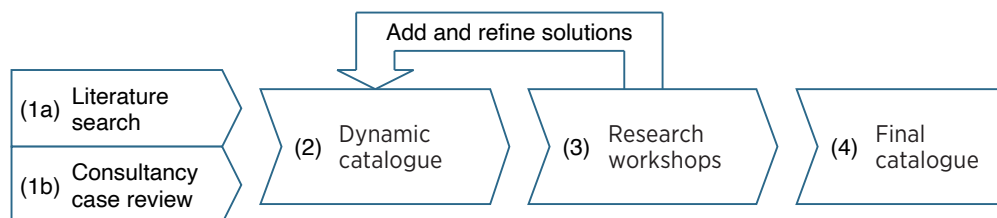


Figure 1: The proposed multi-stage research approach to establishing a catalogue of SME digital solution areas

Referring to Figure 1, the initial working catalogue was generated from academic (1a) and non-academic (1b) case studies. The input from SMEs then built on this initial catalogue. This order enables the refinement of the working catalogue through company feedback in each cycle. When a new solution area was identified during a workshop, we tested it against functional definitions of the existing solution areas to differentiate genuinely new additions from mere changes in wording. We added any new solution area from a relevant source to the set to further comprehensiveness.

Any SME manufacturer that produces discrete products (excluding outsourcing and continuous manufacturing) was eligible for the study to maximize engagement. Multiple participants from the same company, and non-manufacturing companies were excluded from the data set, resulting in the input from a total of 128 manufacturing SMEs. To identify new solution areas, we asked the companies to share any recent digitalisation activities and any concrete plans for the upcoming year before exposing them to the working catalogue. At the end of the workshop, companies were asked again whether they were satisfied with the current options. The working catalogue (stage 4), from the perspective of this study, consisted of 59 solution areas as of end of 2020.

Table 1 - Catalogue of Digital Solution Areas for Manufacturing SMEs

| Category | # | Solution Area |
|--|----|--|
| 1) Data Capture and Visualisation | 1 | Automated visualisation of financial KPI to all relevant function |
| | 2 | Capacity monitoring of human and machine resources |
| | 3 | Condition monitoring of equipment |
| | 4 | Customer and demand data gathering and analysis |
| | 5 | Digital faults monitoring (tracking of re-works and complaints) |
| | 6 | Digital inventory status and reconciliation |
| | 7 | Digital job cards |
| | 8 | Digital job cost variance tracking |
| | 9 | Digital library of typical errors/faults and rectification instructions |
| | 10 | Digital waste recording system (goods, energy, water, etc.) |
| | 11 | Display of production schedule around the shop floor |
| | 12 | Integrated information system between design and production operations |
| | 13 | Monitoring and reporting on working conditions |
| | 14 | Monitoring of lead time |
| | 15 | Problem and context oriented display of information for operators |
| | 16 | Process monitoring (vibration/energy/temperature, etc.) |
| | 17 | Real time emission monitoring |
| | 18 | Real time tracking of internal jobs (location, status) |
| | 19 | Real time waste and emission monitoring |
| | 20 | Traceability, evidence and data of the cost of meeting CSR requirements |
| | 21 | Traceability, evidence and data on product wear and obsolescence |
| | 22 | Traceability, evidence and data on supplier ethos |
| 2) Data Analysis | 23 | Automated bottleneck identification in operations |
| | 24 | Automated bottleneck identification in supply chain |
| | 25 | Automated finished product scan and integration with logistics provider |
| | 26 | Automated generation of CNC code |
| | 27 | Automated job scheduling to human and machine resources |
| | 28 | Automated minimisation of tooling |
| | 29 | Automated optimisation of process parameters |
| | 30 | Automated quoting system for spot pricing |
| | 31 | Automated sustainability index of products (energy, raw materials, etc.) |
| | 32 | Automated tracking and assignment of tools to operations |
| | 33 | Automated visual inspection of shape/finish of goods |
| | 34 | Automated weight check and packaging |
| | 35 | Control procedure for equipment maintenance |
| | 36 | Control procedure for equipment operation |
| | 37 | Control process to manage line side feeds/counters |
| | 38 | Digital cost model for jobs |
| | 39 | Digital cost modelling of disruptions and changes |
| | 40 | Digital supply chain visualisation and decision assistance |
| | 41 | Digitally assisted inbound goods quality verification |
| | 42 | Material arrival predictions |
| | 43 | Optimisation of energy consumption |
| | 44 | Optimisation of machine set-up times |
| | 45 | Optimisation of material flow and travel within operation |
| | 46 | Predictive equipment maintenance |
| | 47 | Weather based scheduling |
| 3) Actuation | 48 | Automated delivery of workpieces and tools to operators |
| | 49 | Automated tool changer / part feeder |
| 4) Support Systems | 50 | Digital management architecture (ERP and MES) |
| | 51 | Digital manufacturing project management system |
| | 52 | Digital purchase order management system |
| | 53 | Digital sales order management system |
| | 54 | Digital methods for employee training (webinars, VR, AR, etc.) |
| | 55 | Digital worker shift management system |
| | 56 | Digital works order management system |
| | 57 | Digitised work instructions, photos and assembly procedures |
| | 58 | Product life cycle management system |
| | 59 | Simulation of tools and processes for virtual process planning |

2.3. The Catalogue of Digital Solution Areas for Manufacturing SMEs

The 2020 working catalogue of Digital Solution Areas, finalised after interacting with 128 SMEs, is presented in Table 1. The solution areas are grouped into the four categories: 1) *Data Capture and Visualisation*, 2) *Data Analysis*, 3) *Actuation*, and 4) *Support Systems*. This classification is similar in style to the production information loop, a common approach to classify cyber-physical systems [12,13]. The first category comprises both *data capture* and *visualisation* solution areas, because capturing data does not in itself solve a specific problem a SME might have. Category 2 contains solution areas that employ analytical methods. These

can be based on data derived from solution areas from category 1, or on existing data within the company. The output can feed into an automated decision algorithm or be used for human decision support. Category 3 consists of actuation-based solution areas. Another recurring theme that was mentioned in many workshops was *Support Systems* (category 4), which replace manual data handling processes, but still require full human interaction to be effective.

Further workshops are being held in 2021 and the catalogue will be updated accordingly.

3. Interpreting the Working Catalogue

In this section we highlight trends observed in the catalogue and discuss company activities supported by the solution areas.

3.1 Catalogue Composition

As indicated in the previous section, the catalogue entries have been broadly categorised under four headings:

- 1) Data Capture and Visualisation
- 2) Data Analysis
- 3) Actuation
- 4) (Decision) Support Systems

Most solution areas identified to date (end of 2020) are in the categories of *Data Capture and Visualisation* (37%), and *Data Analysis* (42%). This could be a reflection of the fact that many SME manufacturers are still in the early stages of digitalisation [14]. Gathering and visualising data can be an important first step towards more digitalisation. It is, however, noticeable that only two solution areas are in the category of *Actuation*. A potential reason is that companies could perceive actuation as a core function

for some manufacturing processes rather than as a digitalisation activity. Different to the categories 1-3, the solution areas in *Support Systems* mostly represent software solutions for management functions that can act independently from other solution areas in the catalogue. Notable exceptions are *digitised work instructions* (no. 57), which is targeted at shop floor workers, and *ERP/MES systems* (no. 50). We emphasise that none of the solution areas identified are *new*. The reader is reminded that the aim of the catalogue is simply to capture digital solution areas that SME manufacturers consider important.

3.2 The Catalogue and SMEs

3.2.1 The Catalogue and Business Areas

To better understand how the catalogue items apply to different areas of the manufacturing business, Figure 2 maps each solution area to a company activity, derived from Porter's generic value chain [15]. Each solution area is represented only once, in the most relevant activity. However, many of the solution areas can provide benefits to other company activities as well.

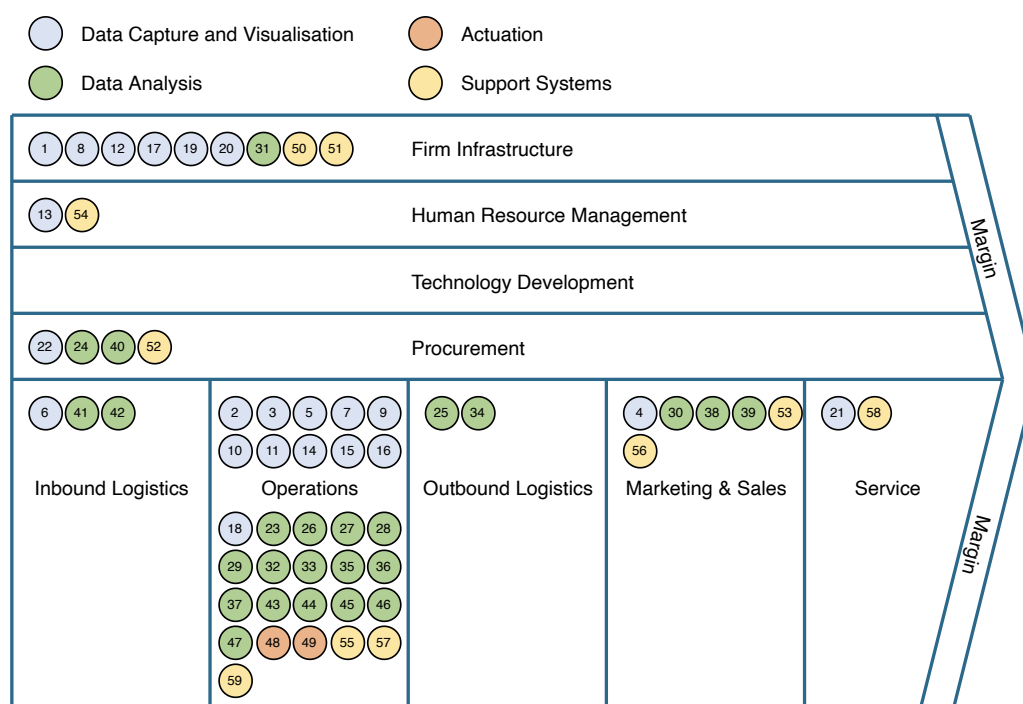


Figure 2: Allocation of the catalogue items to the activities of manufacturing SMEs, based on the generic value chain of a firm [15]

Most solution areas fall under *Operations* (53%) or *Firm Infrastructure* (14%). The heavy focus on *Operations* is not surprising for manufacturing SMEs, as the category includes all activities that contribute to the main value the company provides (such as producing a product). Due to the heavy representation, we have further decomposed this area as shown in Figure 3.

Firm Infrastructure includes activities such as management, planning, and accounting [15]. Many of the participants were management level representatives of the SMEs, so specific challenges in this area might be more salient to them. Another possible explanation is that infrastructure functions in SMEs might be staffed with fewer workers than operational functions so that the potential upside of digital solutions is very high. The focus on *Data Capture and Visualisation* solution areas is expected then, as better data availability can help to provide a better overview of the company.

Notably, no solution areas to address the *Technology Development* were proposed. This is most likely due to the scope of this study, focussing on operations

in manufacturing companies. While a portion of the participants develop products, they likely saw their priority needs in other areas. However, some of the solution areas also provide benefits for technology development (for example solution areas 12, 16, 29, or 57). Similarly, the fact that the participants (being SMEs) have small workforces can explain the low representation of solution areas for *Human Resource Management*.

Interestingly, the solution areas relating to *Procurement* focus on operational aspects of supply chain management, but not on lowering the cost of procurement (e.g., materials, or costs of the purchasing process). Only few solutions in the areas of *Inbound* and *Outbound Logistics* were identified. A possible reason could be that these categories are closely connected to *Operations* and can benefit from several of the solution areas there. For example, *tracking of complaints* (5) and *library of recurring faults* (9) could also be of value for outbound logistics, while *automated job scheduling* (27) could help with fluctuations in the inbound logistics.

3.2.2. The Catalogue and Manufacturing Operations

In this section we examine the role of different catalogue entries in supporting the operations area.

Figure 3 (overleaf) shows a more granular overview of the category *Operations*. The subcategories are derived from examples in Porter's original work [15]. *Production* is named in a generic way to include any relevant transformative step other than assembly (e.g., machining, moulding). Some solution areas provide overarching benefits to multiple of the six subcategories. Examples are *digital job cards* (7), which travel with a product and can be beneficial in both production and assembly (and potentially other steps) and *digitised work instructions, photos and assembly procedures* (57), which can provide value in any process where human work is involved.

A further observation is that all solution areas that can facilitate *Assembly* can also facilitate the *Production*. Many of the additional solution areas in *Production*

area of the *Data Analysis* type and address process optimisation. A potential reason could be that SMEs often use more advanced equipment in their core production processes (such as CNC machines), while assembly procedures are mostly manual, thus profit less from advanced analytics.

Scheduling can be facilitated by a variety of solution areas as well, demonstrating the potential modularity and incrementality of solutions. While the solution area *automated job scheduling to human and machine resources* (27) is part of the catalogue, such an automated system is not the only way the activity area *Scheduling* can be enhanced. *Accurate monitoring of resources* (2), *real time tracking of internal jobs* (18), or a *digital worker shift management system* (55) could all be valuable additions to the company while keeping the actual scheduling process manual.

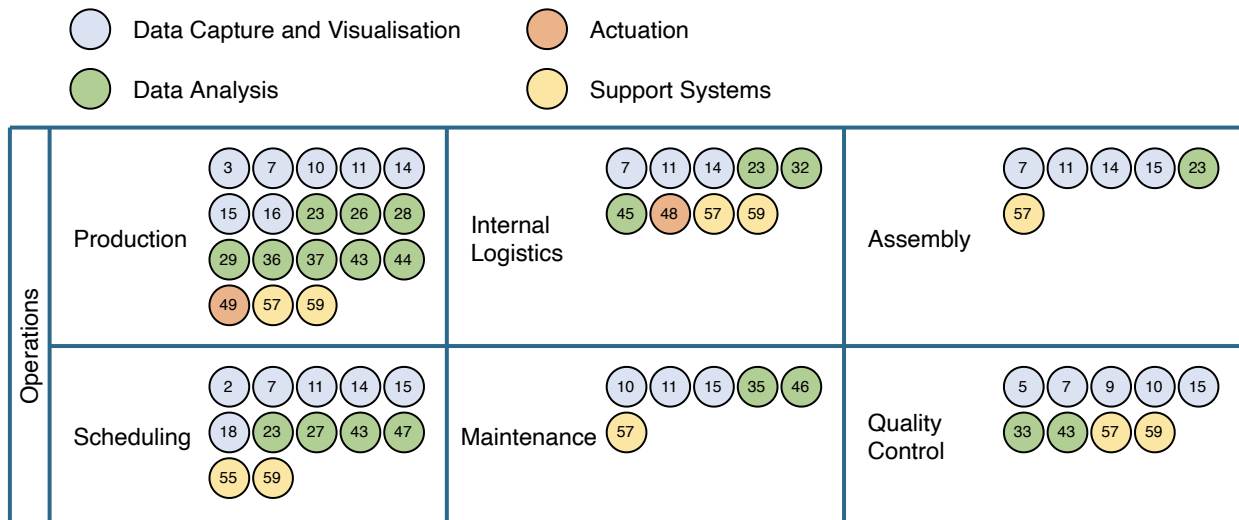


Figure 3: Allocation of the catalogue items in the area of operations [15]

4. Summary

This white paper has outlined a working catalogue of digital solution areas relevant to manufacturing SMEs. The findings are of high practical relevance to manufacturing SMEs, researchers, and businesses in the space of digitalisation. Individual SMEs can profit from the catalogue by saving time on researching potential digitalisation projects for their business, and gaining a research-based overview of the available options. Over 99% of SMEs in the study rated at least one of the digital solution areas as being highly beneficial to their business, confirming the comprehensiveness of the set.

The catalogue can also help focus research endeavours on high-impact issues in digitalisation for SMEs. For solution providers the catalogue provides a prioritisation of future developments that can be expected to be of high relevance for potential customers.

The catalogue presented here was based on data collected up to the end of 2020. It is intended that the catalogue be updated annually to reflect new applications that are identified.

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Catalogue of Shoestring solutions

A full catalogue of solutions will be made available on the website.

Please contact **contact@digitalshoestring.net** with any queries.





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