23rd Cambridge International Manufacturing Symposium
University of Cambridge, 26 – 27 September 2019

Digital Transformation in the Automotive Supply Chain

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Abstract

In this paper, we begin the process of developing practice-based research problems and questions concerning supply chain digitalization in the automotive industry. Specifically, our focus is on understanding organizational conditions facilitating supply chain and production digitalisation and its role in performance improvement. Therefore, as a first step we organized a research workshop during last year's Cambridge Center for International Manufacturing (CIM) Symposium with 30 executives representing multiple tiers of the automotive supply chain. The purpose was identifying key themes and patterns amongst these themes, which provides a basis for a practitioner-based, impact led research agenda. We presented the executives with ten digital scenarios developed by CIM, and recorded responses their responses to each scenario in a template of the ten scenarios. Using social network analysis (SNA) we then interrogated the qualitative data to identify: "inter-codal" patterns, linkages and relationships.

Keywords: Automotive Industry; Workshop; Social Network Analysis

1. Introduction

Digitalisation is the use and adoption of external digital technologies (i.e. resources such as machine learning, IoT, big data and blockchain) by organizations, to improve supply chain and operational performance (Holmstrom and Partanen, 2014). Whilst there is a lot of emphasis on the strategic adoption of digital technologies the work on operational feasibility, research on maturity and supply chain implementation is scarce (Seyedghorban et al., 2019). In order to explore implementation from a practice-based perspective, this paper presents the findings of an expert workshop of OEM's (original equipment manufacturers), OES's (original equipment suppliers, Tier 1), an automotive trade association, and high technology consultants that we organized in a research workshop at the 22nd Cambridge International Manufacturing Symposium, in 2018.

We had thirty participants who attended the half-day workshop and participated in a follow up interview survey. Using KNIME, we deployed text analytics to perform qualitative coding analysis on the results. The aim is to identify the most common occurring and co-occurring terms within a network encompassing the terms that have been identified from the ten scenarios. KNIME uses six different steps to process texts: reading and parsing documents, named entity recognition, filtering and manipulation, word counting and keyword extraction, transformation and visualization. It provides a neutral coding facility free of human bias.

2. Method

Ten digital scenario topics were presented to the participants/interviewees. These are as follows: i. Automated e-sourcing (seamlessly connected automated replenishment in line with real-time KPI monitoring with predictive disruption analytics; ii. Digital factory design - digital 3D modelling system for factory layout design, process and material for simulation; iii. Real time factory scheduling. Advanced factory execution systems with sensor enabled smart devices, real time data, KPI monitoring, predictive maintenance; iv. Flexible factory automation - advanced manufacturing plant/machine reconfiguration; scale flexibility, varied levels of human-robot collaboration; v. Digital production process - application of digital production processes (i.e. additive manufacturing, continuous processing) with advanced process analytics; vi. E-commerce fulfilment - web based order management (configuration, pricing etc) and inventory deployment to multiple points of sale, covering last mile and direct delivery (all tiers through to end users); vii. Extended supply chain (near) real time monitoring - extended end to end supply chain visualisation "watch towers" for near real-time monitoring and decision making; viii. digital product quality - for connecting "traceability islands back from customers to suppliers (not cause analytics); vix. Digital supply network design - design tools to architect supply network configuration - optimization and visualisation of site location, capacity, inventory etc; and x. Product lifecycle management for next generation systems that provide accurate, up-to-date product information accessible throughout the value chain and product lifecycle.

Each topic scenario was considered by the practitioners who were required to fill out a template with their responses to five different categories of each scenario. After a description of the scenarios, the thirty delegates were split into six groups of five and then given 30 minutes to discuss as a team and respond individually to each of the following categories: i. key opportunities; ii. key threats and uncertainties; iii. enabling technologies; iv. enabling skills, know-how and v. key activities to realising the scenario. A facilitator was on hand to assist with explaining and clarifying the activities for completing each scenario.

3. Results and findings

Table 1 summarises the key findings of the identification exercise to discover the key opportunities, threats and enabling skills and technologies and key actions to realise the scenario.

Table 1. Digitalisation opportunities, actions, threats and enabling skills and technologies.

Opportunities	• Autonomous predictive maintenance • Integrate web-based ordering with consumer preferences • How to manage capacity profiles? • Peak pricing models • No more showrooms/ new retail modes • New ownership/subscription models • Shared capacity • How to differentiate in a commoditized world • Optimum part production – through life-cycle • Improved flexibility in face of disruptions	• Transparency • Map Mobility • Ahead of the competition • Reduce end-to-end lead time • Joining systems • Security – reduces cost, requires training • Customer satisfaction, custom detail • Real-time information quality • Control • Knowing which sites are affected and impacts of disruptions	• Help to understand complexity • Real-time location • Scenario planning for supply chain disruptions • Predictive analytics (storage, inventory) • Fail prediction and maintenance • Managing capacity (how much? How to leverage?) • Improved sustainability • Self-organised hyper efficiency • Flexibility in customisation • Improved forecasting • Dynamic response to change (highly focused systems) • Reduced inventory levels • Sunk costs leverage resource efficiency
Threats	• Shared capacity • Privacy • System level capacity planning • Job shifts • Import/export regimes • Software trust • More engineers with high kill sets required • Tracking • Climate change	• Intrusive government • Cost • Tier level coding • Security • Increased uncertainty in regulatory environment • Demand uncertainty	• Not having right competences/capabilities • Tariffs • Brexit/Trade challenges • Political uncertainty in other countries • Environmental conditions/disruptions
Enabling Technologies	• Cloud based services • Real-time simulation • Algorithms • Continuous scanning • Real-time computing • Connectivity • Cloud computing	• Coms forecasting data • Blockchain • Digital connection • Tracking ability • Equipment and fast communications	• Legacy knowledge • Simulation/modelling • R&D, Supply • AI/Blockchain – parts authentication • RFID • Connectivity between different systems
Enabling Skills	• Convenience v. cost • Communication skills – negotiator • System data analytics	• Empowering • Technology knowledge • Need for engineering	• How to handle dark data/data lakes • Change management skills

	• Comprehensive cross-functional business knowledge	• Big numbers not specialised • Not automated	• Technology for tracking, transportation and traceability • Curious/Risk Taker/Self Assured
Key actions to realise the scenario	• Software competitions • Small and independent-led networks • Technology push demand may come later • Car sensors connected to infrastructure sensors • Policy and regulatory challenges- how will connected cars. • Models primarily designed for urban areas not so good in rural areas. • Identify areas of capacity need • System-level capacity planning • SR data trusts	• Better quality supplier • Government monitoring • Control data sharing • Auditing • Data protection • Institutions and regulations • Legal • Compliance • Collaboration • Skills • Policy push to connect different stakeholders • Mapping supply chain against products	• VDVP • Simulation • e2e visibility • Knowing what tech is useful • Setting common and minimum standards on digital quality • IBM's • Embedding into University education • Need to deeply integrate e2e players • Automated vehicles • Government regulations • People preference • Transport times • Delays, parameters or product and vehicle movement

Not shown in the table, but the most popular scenario in terms of depth and breadth of response was that of digital supply network design. Whilst the least popular by far was the digital product lifecycle management.

3.1 Text analysis

Adopting the text analysis procedures of Roberts (2000) and Mayring (2004) we explored inter-codal patterns across the ten scenarios and five categories. Pokorny et al. (2016) explains that: "… *depicting codes applied to a text as a network enables the representation and communication of the complex interrelations between codes, beyond code co-occurrence matrices. Although both represent relations between pairs of codes, the network graph provides the relation between a given pair of codes in context, and in relation to all the other codes in the network (i.e., in the workshop*)" (p. 1). The networks are also created using predefined criteria (i.e., chronology) to indicate the relations between codes, rather than on the researcher's interpretation of code relations within a given type of coding (Attride-Stirling, 2001; Carley and Palmquist, 1992). This means that measures derived from the relations between codes are data-driven and not researcher-driven, allowing others the ability to reproduce the graphs from the same code location data. This offers researchers a way to increase the transparency of the evidence used to support their research conclusions.

3.2 Network graphs

The creation of network graphs also allows researchers an opportunity to view their data in a novel way that provides insights and drives further analysis. In Figure 1 below, the network diagram presents the key co-occurring relationships between the different nodes. We have shaded in red the highest density of node relationships. The network statistics are summarised in Table 2. This enables thematic clusters to be identified and provided an important basis for complex and practice driven research insights (i.e. phenomena-driven research and applied problem identification, with respect to digitalisation (Gallien et al., 2015)). Enabling (skills and technologies) had the most connections to the other terms (n = 68). The highest density of connections it had were linked to "quality", "after-market", "control", "government", "testing", "real-time", "management" and "products". These themes were the most-strongest connected across the ten scenarios. This preliminary identification of emerging nodal relationships provides an important precursor for more detailed critical analysis of relationship patterns as we progress the research project to extended case study development (Pokorny et al., 2016).

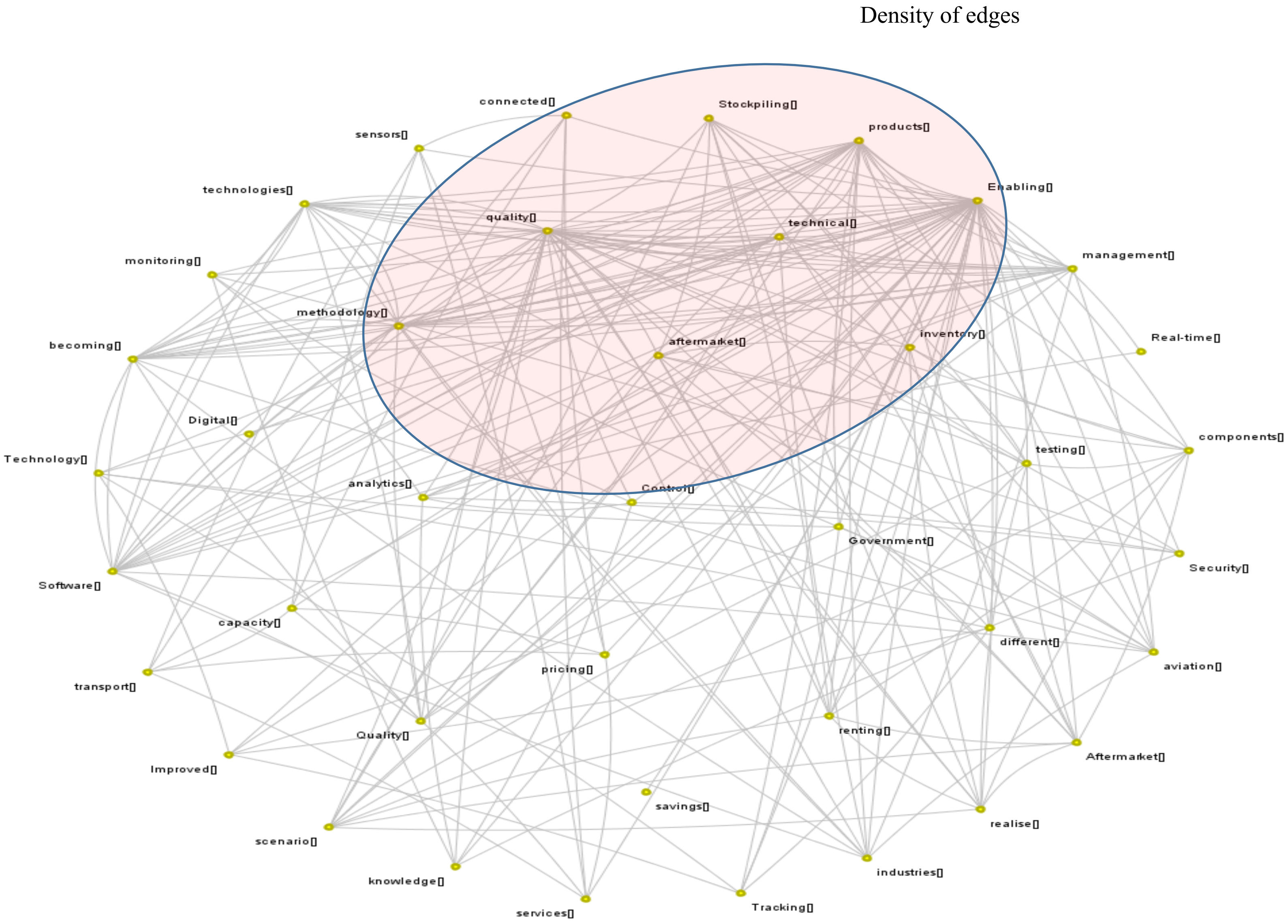

Figure 1. Network of co-occurring relationships across the ten scenarios.

Table 2. Network statistics.

Label	Degree	Weighted Degree	Eccentricity	closnesscentrality	harmonicclosnesscentrality	betweenesscentrality
Enabling	68	90	1	1	1	361.333333
Opportunities	29	36	3	0.62963	0.754902	92
quality	26	36	2	0.888889	0.9375	144.833333
technologies	24	36	0	0	0	0
Scenario	22	27	3	0.545455	0.652778	91.833333
products	18	27	2	0.692308	0.777778	59.5
regulations	17	18	1	1	1	11
analytics	17	18	2	0.727273	0.8125	85.833333
Digital	16	18	2	0.564815	0.614754	4.166667
technical	10	18	1	1	1	0
management	10	18	2	0.647059	0.727273	0
Software	10	18	2	0.7	0.785714	1
predictions	9	9	0	0	0	0
testing	9	9	0	0	0	0
transport	9	9	0	0	0	0
savings	9	9	0	0	0	0
vehicles	9	9	0	0	0	0
efficiency	9	9	1	1	1	0
equipment	9	9	1	1	1	0
services	9	9	1	1	1	0
customisation	9	9	1	1	1	0
monitoring	9	9	2	0.5625	0.611111	0
sensors	9	9	1	1	1	0
decisions	9	9	1	1	1	0
Transparency	9	9	1	1	1	0
competencies	9	9	1	1	1	0
knowledge	9	9	2	0.588235	0.65	0
pricing	9	9	1	1	1	0
Production	9	9	4	0.373134	0.443333	0
product	9	9	3	0.47619	0.583333	0

4. Conclusion

With 68 connections across the network, the theme of enabling (skills and technology) is central to the discussion by our automotive executives on digitalisation and opportunities. As well an enabling digitalisation it was associated with emerging opportunities across the ten scenarios (with respect to “quality”, “inventory”, “control” and (preventing) “stock-piling”). Though there were also a lot of threats identified concerning digitalization with respect to “risks”, “disruption”, “privacy”, “costs” and “intrusiveness”. By far the most interest and data was provided by the executives for the “digital supply network design” scenario. The least popular was “product life-cycle management”. Therefore, with respect to practice-based problem and topic identification to guide our future research investigation, it would appear that the scenario topic of investigation which has the most interest from practitioners, would be that of supply network design. Further, that we would be looking at problems, phenomna and insight-based research exploring supply network design realisation from the perspectives of enabling (skills, technology) and its close assocation with issues of quality, technology, products, regulations, analytics, technical, management and software. There would be a need to balance this with an analysis of the threats, risks and disruptions of automotive organizations implementing digital supply network design.

Acknowledgments

We would like to acknowledge the work of Dr Jagjit Singh Srai for his invaluable support with the promotion and scenario facilitation.

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