TECHNICAL UNIVERSITY OF CRETE

DOCTORAL DISSERTATION

Strategies and implication of supply chain integration with blockchain

Στρατηγικές και επιπτώσεις από την ενσωμάτωση τεχνολογίας αλυσίδας κατανεμημένης εγγραφής (blockchain) στην εφοδιαστική αλυσίδα

Author:

Efstathios Papanikolaou

Supervisory Committee:

Prof. Vassilios Moustakis
Prof. Fotios Passiouras
Prof. Jannis Angelis

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctorate of Philosophy

in the

Management Systems Laboratory

School of Production Engineering and Management

Chania, 2023

ΕΠΤΑΜΕΛΗΣ ΕΞΕΤΑΣΤΙΚΗ ΕΠΙΤΡΟΠΗ

Τίτλος (ελληνικά/αγγλικά):

Στρατηγικές και επιπτώσεις από την ενσωμάτωση τεχνολογίας blockchainστην εφοδιαστική αλυσίδα

Strategies and implication of supply chain integration with blockchain

ΔΙΔΑΚΤΟΡΙΚΗΔΙΑΤΡΙΒΗ

(Ονοματεπώνυμο διδάκτορα)

ΠΑΠΑΝΙΚΟΛΑΟΥ ΕΥΣΤΑΘΙΟΣ

ΤΡΙΜΕΛΗΣ ΣΥΜΒΟΥΛΕΥΤΙΚΗ ΕΠΙΤΡΟΠΗ

1. Βασίλειος Μουστάκης (καθηγητής),(Επιβλέπων)
2. ΦώτηςΠασιούρας (καθηγητής),
3. Γιάννης Αγγελής (αναπληρωτής καθηγητής)

Εγκρίθηκε από την επταμελή εξεταστική επιτροπή την: 28 / 08/ 2023

1. (Καθηγητής, Βασίλειος Μουστάκης)………………………… (υπογραφή)

2. Καθηγητής, Φώτης Πασιούρας)………………………………

3. (Αναπληρωτής Καθηγητής, Γιάννης Αγγελής)………………

4. (Καθηγητής, Κωνσταντίνος Ζοπουνίδης)…………………

5. (Καθηγητής, Ιωάννης Μαρινάκης)…………………………

6. (Αναπληρωτής Καθηγητής, Στυλιανός Τσαφαράκης)………

7. (Επίκουρος Καθηγητής, Βασίλειος Ζείμπέκης) ……………

“Technology itself has no singe objective value. When it is commercialized in some way by a business model then its economic value becomes apparent”

(Chesbrough, 2010)

Acknowledgements

I would like to thank Prof. Vassilios Moustakis and Prof. Jannis Angelis for their recommendations and patience on completing this study. Their guidance and invaluable advice have been crucial in my doctoral studies. They helped me cope with study challenges and perform the research required without diverging from research objectives. I am deeply obliged to both of them. My hope is that this dissertation leaves something important behind and that other scientists will find the findings useful in advancing their own research in the field.

Publications based on PhD dissertation.

Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

Papanikolaou, E., Angelis, J. and Moustakis, V. 2023.Unique or adjustable business model for DLT? Journal of Business Models, Vol 11, https://doi.org/10.54337/jbm.v11i1.7149

Conferences announcements based on PhD dissertation.

Papanikolaou, E., Angelis, J. and Moustakis, V. 2022. Unique or adjustable business model for DLT? Business Model Conference 2022, June 2022, hosted by the IAE Lille University School of Management

Papanikolaou. E., Angelis, J. and Moustakis, V. 2022. DLT impact on information logistics in manufacturing value streams. ERS Conference 2022, Council of Supply Chain Management, June 2022, hosted by the Politecnico di Milano

Papanikolaou, E., Angelis, J. and Moustakis, V. 2022. DLT ecosystem actor roles and their contribution in ecosystem dynamics and sustainability. 3rd Symposium on Circular Economy and Sustainability, June 2022, Chania Greece, hosted by the Technical University of Crete

Papanikolaou. E., Angelis, J. and Moustakis, V. 2023. Blockchain as an alternative value creating and value capture mechanism. The Early Career Researchers Conference, April 2023, hosted by the Manchester Alliance Business School

Papanikolaou. E. 2023. Blockchain adoption in manufacturing ecosystems. Ecosystems Day. April 2023, hosted by the Vrije School of Business & Economics, Amsterdam.

Papanikolaou. E., Angelis, J. and Moustakis, V. 2023. Business model ontology for Distributed Ledger Technology. Business Model Conference 2023, June 2023, hosted by the University of Bologna.

Papanikolaou. E., Angelis, J. and Moustakis, V. 2023. Distributed Ledger Technology ecosystem actor roles for ecosystem dynamics and sustainability. European Group of Organizational Studies (EGOS), July 2023, hosted by the University of Cagliari.

Papanikolaou. E., Angelis, J. and Moustakis, V. 2023. Blockchain Adoption Considerations of a Global Manufacturer. Production and Operations Management Society (POMS), July 2023, hosted by the Rennes School of Business.

Papanikolaou. E. 2023. Governance act for Business Model Innovation in emerging DLT ecosystems. British Academy of Management (BAM) Doctoral Symposium, Sept 2023, hosted by the University of Sussex

Abstract

Distributed Ledger Technology (DLT), or else blockchain, enables new ways of inter-firm interaction in a networked environment. DLT is in its primitive stage of development and many organizations in various industries experiment with it to realize its boundaries and benefits that stem from it in practice. In today's globalized economy, effectiveness and efficiency of supply chain operations depend upon the synchronization and coordination of organization's processes, departments and external entities, that intersect supply chain operations. Those supply chain touchpoints seem to leave some space for DLT adoption at supply chain level, due to the trust issues, uncertainties and vulnerabilities that are raised in relationships among interacting entities. The same applies in the case that those touchpoints are referred to the internal or external intersections of organization's supply chain processes for each individual supply chain entity.

Although DLT has long way to go until widely adopted, companies proceed mainly with pilot supply chain implementations to explore its benefits. Supply chain digitalization is becoming the center stage in developing manufacturers' competitive advantage. However, research shows that supply chains are facing information exchange and trust issues and that makes DLT an ideal candidate to address those challenges. Technology itself has no singe objective value. When it is commercialized in some way by a business model then its economic value becomes apparent. Business model innovation is associated with the capability of an organization to commercialize new ideas and technologies or to depict the variations on a generic value chain. DLT brings fundamental changes in the way that value is exchanged, transactions are executed among ecosystem actors and ecosystems interact. Business model represents the value logic of an organization and articulates how a company goes to the market to implement a strategy. It is the link between the strategy and the operative implementation.

Existing literature has discussed the potential of DLT to transform the supply chain, but limited work has been taken into exploring the impact of DLT to the respective business model. Although business model innovation literature is referred to the aspect of technological advances as one of its main drivers, the impact of DLT implementation at supply chain level on manufacturers' business model has not been addressed. We acknowledge and set at the center of our research the fact that in a highly dynamic

environment, where different types of relationships coexist, supply chain collaboration is inextricably linked with information sharing capabilities and trust dynamics developed among interacting parties. To close that gap in literature, we select an inductive, qualitative multiple case study approach to answer the *first main research question (mRQ1) of "What are the implicit effects in business model that stem from DLT adoption", under a manufacturing supply chain context*. We identify how DLT adoption under a manufacturing supply context leads to activities, intents and decisions that affect organization's business model elements. We map how and which business model dimensions are affected and provide managers a method to analyze and assess which DLT related supply chain decisions will affect which business model dimensions, we present the respective process model.

Peer-to-peer transactions among network members, the large number of network participants that ensure both DLT security and the need for positive network effects, highlight the need to argue for an ecosystem approach, where actors create value for actors, when investigating DLT adoption. DLT can be adopted and drive value creation in different ecosystem types, Therefore, before we explore DLT adoption, under a manufacturing supply chain context, we need to clarify what ecosystem type should we consider when we discuss DLT and direct our research regarding the first main research question (mRQ1) based on the selected ecosystem type analogies to DLT ecosystem conceptualization. We argue that the economic community consisted of organizations, that although independent, are connected and interact through DLT form the DLT ecosystem. DLT can be applicable in many ecosystem types. However, little research has been done on how DLT works in all ecosystem types. We acknowledge specific ecosystem characteristics in a DLT network of actors and argue that there are similarities between various ecosystem types. Our study extends DLT and ecosystem literature by answering the *research sub-question (subRQ1.1) "How do ecosystem types make fit to DLT?".* We build upon the software, technological, digital, innovation, product and service ecosystem literature and examine how do they match to DLT ecosystem. We find out that these ecosystems can be part or subset of the DLT ecosystem, but it is the business ecosystem type that fits better to DLT ecosystem conceptualization. To make this apparent we analyze the characteristics, definitions and enablers of business ecosystem and identify the analogies between DLT and business ecosystem.

We argue that when we investigate DLT adoption under an ecosystem conceptualization we need to consider the roles that ecosystem actors hold in it under the context of ecosystem sustainability. DLT value lies in the sustainability of the DLT network, since value created in DLT network is collectively produced by its members. In that way we can investigate more accurately the DLT adoption causations, as referred to mRQ1, since different DLT ecosystem roles in a highly dynamic environment led to different DLT adoption incentives. We build upon ecosystem conceptualization, due to DLT network effects and extend DLT literature by answering the *research sub-question (subRQ1.2) of "How DLT ecosystem actors based on their role, contribute to ecosystem sustainability?"*. Little research has been done on how DLT actor roles affect DLT ecosystem sustainability in a highly dynamic environment, where exchange of trusted data plays fundamental role in meeting DLT ecosystem sustainability.

Based on the most recent DLT developments, we identify the ecosystem dynamics for the DLT business ecosystem type as identified when answering the subRQ1.1 and propose the factors that should be considered for its sustainability. Under that condition, we emphasize in network effects created in ecosystem and cluster actor roles according to their dominant or non-dominant position they hold in it. To gain a holistic overview of DLT supply chain adoption we expand our research beyond the profound interaction of organization's supply chain with entities external to the organization, as answered by the subRQ1.1. Therefore, we argue that we also need to look internal to the organization for the respective DLT in-house supply chain adoption causations. DLT does not seem, at least at first sight, to have much to contribute unleashing its potential under an in-house supply chain context. In that part of our research, we initially investigate whether internal supply chain touchpoints leave ground for conveying DLT benefits, thus answering the *second main research question (mRQ2) of 'How DLT adoption causations at in-house supply chain level impact organization's business model?".* In the absence of evidence in literature we base our study on carefully selected qualitative inductive single case study research. Based on the findings we set out to advance our understanding of DLT adoption impact on the business model dimensions. To understand to what extent business model is affected by DLT implementation at in-house supply chain level, we initially unpack it into its dimensions and evaluate how each one of them is affected by DLT implementation root causes. After we have complete overview of the processes that led to DLT in-house supply chain adoption causation. we portray a process model, that reflects the process of DLT in-house supply chain adoption, the dynamic relationships among the emergent concepts and its impact on organization's business model.

Industry 4.0 is expected to support and accelerate lean principles (Davis. et al, 2020) Under that prism and in the absence of literature of how DLT adoption at in-house supply chain level, could impact manufacturing leanness, we build upon the findings of the mRQ2 to answer the research sub-question (subRQ2.1) of "To what extend could DLT adoption impact manufacturing leanness?" Based on the elite informants engaged in single case study data collection for the purpose of answering the mRQ2, we collected and analyzed data under the assumption that DLT adoption will only affect the information flow and no other material flow lean improvement technique will be considered. We employ the value stream mapping methodology (VSM), to depict the simulated future state under our assumptions We eventually illustrate and evaluate which and to what extend manufacturing streams throughput time (TT) is impacted.

Manufacturing leanness improving dilemma should not be DLT or nothing. Value added to in-house supply chain operations, due to DLT adoption, reveals that it should not be seen as a stand-alone solution but rather as combination with other systems or data sharing processes already in place. Moreover, results indicate that DLT provide an additional option for optimization. Classic DLT argument is that it resolves trust issues between interacting actors. However, beyond that it relates the transaction focused approach as altered due to DLT adoption, to manufacturing optimization.

Executive Summary Conclusion (GR)

Η τεχνολογία Distributed Ledger Technology (DLT), ή αλλιώς blockchain, επιτρέπει νέους τρόπους αλληλεπίδρασης μεταξύ επιχειρήσεων σε ένα δικτυωμένο περιβάλλον. Το DLT βρίσκεται στα αρχικά στάδια της ανάπτυξής του και πολλοί οργανισμοί σε διάφορους κλάδους πειραματίζονται προκειμένου να ανακαλύψουν τα οφέλη αλλά και τους περιορισμούς που απορρέουν από την υιοθέτηση της στην πράξη. Στη σημερινή παγκοσμιοποιημένη οικονομία, η αποτελεσματικότητα και η αποδοτικότητα των λειτουργιών της εφοδιαστικής αλυσίδας εξαρτώνται από τον συγχρονισμό, τον συντονισμό των διαδικασιών του οργανισμού, των τμημάτων αλλά και των εξωτερικών οντοτήτων, που αλληλοεπιδρούν με τις λειτουργίες της εφοδιαστικής του αλυσίδας. Η αποκεντροποίηση στη διαχείρισης της πληροφορίας και η μη δυνατότητα αλλοίωσης της πληροφορίας που ανταλλάσσεται αποτελούν βασικούς πυλώνες της τεχνολογίας DLT. Ένεκα των ζητημάτων εμπιστοσύνης που εγείρονται στις σχέσεις μεταξύ αλληλοεπιδρώντων οργανισμών σε επίπεδο εφοδιαστικής αλυσίδας το DLT φαίνεται να αποτελεί μια λύση που έρχεται να απαντήσει σε αυτά τα ζητήματα. Ποιο συγκεκριμένα στη παρούσα μελέτη θα εξεταστούν αρχικά οι λόγοι υιοθέτησης του DLT βάση των αλληλεπιδράσεων στα σημεία επαφής της εφοδιαστικής αλυσίδας κάθε οργανισμού με εσωτερικές ή εξωτερικές οντότητα.

Αν και το DLT έχει πολύ δρόμο να διανύσει μέχρι να υιοθετηθεί ευρέως, οι εταιρείες προχωρούν κυρίως σε πιλοτικές, στοχευμένες, μικρής κλίμακας εφαρμογές σε επίπεδο εφοδιαστικής αλυσίδας για να διερευνήσουν τα οφέλη του στα πλαίσια των προσπαθειών ψηφιοποίησης της. Η ψηφιοποίηση της εφοδιαστικής αλυσίδας βρίσκεται το επίκεντρο της προσπάθειας για την ανάπτυξη ανταγωνιστικού πλεονεκτήματος των εταιρειών που ενσωματώνουν γραμμές παραγωγής προϊόντων. Ωστόσο, διαφορετικές έρευνες και μελέτες δείχνουν ότι οι αλυσίδες εφοδιασμού αντιμετωπίζουν προβλήματα ανταλλαγής πληροφοριών καθώς και ζητήματα εμπιστοσύνης στην ανταλλαγή πληροφορίας και αυτό καθιστά το DLT ένα ιδανικό υποψήφιο για την αντιμετώπιση αυτών των προκλήσεων. Η ίδια η τεχνολογία δεν έχει καμία αντικειμενική αξία από μόνη της, παρά μόνο όταν εμπορευματοποιείται με κάποιο τρόπο μέσα από ένα επιχειρηματικό μοντέλο. Τότε η οικονομική της αξία γίνεται εμφανής. Η αλλαγή του επιχειρηματικού μοντέλου συνδέεται με την ικανότητα ενός οργανισμού να εμπορευματοποιεί νέες ιδέες και τεχνολογίες ή να απεικονίζει τις παραλλαγές του σε μια γενική αλυσίδα αξίας. Το DLT επιφέρει θεμελιώδεις αλλαγές στον τρόπο με τον οποίο ανταλλάσσεται η πληροφορίας, εκτελούνται οι συναλλαγές μεταξύ των μελών του επιχειρηματικού οικοσυστήματος και του τρόπου που αυτά τα οικοσυστήματα αλληλοεπιδρούν μεταξύ τους. Στη μελέτη μας υιοθετούμε της θεώρηση ότι τα δεδομένων του κάθε οργανισμού αποτελούν στοιχεία με αξία και πιο συγκριμένα αποτελούν περιουσιακό του στοιχείο (data-as-an-asset). Το επιχειρηματικό μοντέλο αντιπροσωπεύει τη λογική της δημιουργίας αξίας ενός οργανισμού και αντικατοπτρίζει τον τρόπο με τον οποίο μια εταιρεία εφαρμόζει την στρατηγική της. Είναι ο σύνδεσμος μεταξύ της στρατηγικής και της λειτουργικής εφαρμογής των εσωτερικών της διαδικασιών.

Η υπάρχουσα βιβλιογραφία εξετάζει τις δυνατότητες του DLT να μεταμορφώσει την εφοδιαστική αλυσίδα. Περιορισμένη όμως έρευνα έχει γίνει ως προς τη διερεύνηση του επιπτώσεων της υιοθέτησης της τεχνολογίας DLT στο ευρύτερο επιχειρηματικό μοντέλο της επιχείρησης. Αν και στη βιβλιογραφία οι καινοτόμες αλλαγές των επιχειρηματικών μοντέλων αναφέρονται κυρίως στην πτυχή των τεχνικής προόδου ως έναν από τους κύριους μοχλούς εξέλιξής τους, η επίπτωση που θα έχει η εφαρμογή του DLT στην αλυσίδα εφοδιασμού, στο επιχειρηματικό μοντέλο των επιχειρήσεων που λειτουργούν γραμμές παραγωγής (manufacturer), έχει εξεταστεί ελάχιστα. Αναγνωρίζουμε και θέτουμε στο επίκεντρο της έρευνάς μας το γεγονός ότι σε ένα εξαιρετικά δυναμικό περιβάλλον, όπου συνυπάρχουν διαφορετικοί τύποι σχέσεων μεταξύ των επιχειρήσεων που αλληλοεπιδρούν, οι συνεργασίες των εφοδιαστικών αλυσίδων είναι άρρηκτα συνδεδεμένες με τη δυνατότητα ανταλλαγής πληροφοριών και τη δυναμική εμπιστοσύνης που αναπτύσσεται μεταξύ των αλληλοεπιδρώντων μερών. Για να καλύψουμε λοιπόν αυτό το κενό στην υπάρχουσα έρευνα, επιλέγουμε μια επαγωγική, ποιοτική προσέγγιση μελέτης πολλαπλών περιπτώσεων (multiple case studies) προκειμένου να απαντήσουμε στο πρώτο κύριο ερευνητικό ερώτημα, και πιο συγκεκριμένα:

(mRQ1) «Ποιες είναι οι επιδράσεις στο επιχειρηματικό μοντέλο που προκύπτουν από την υιοθέτηση του DLT στην εφοδιαστική αλυσίδα επιχειρήσεων με γραμμές παραγωγής (manufacturers)».

Έρευνα: Ακολουθήθηκε η μεθοδολογία της επαγωγικής ποιοτικής έρευνας πολλαπλών περιπτώσεων (multiple case study qualitative inductive research). Η συλλογή δεδομένων έγινε μέσα από 2 γύρους ημι-δομημένων συνεντεύξεων με διευθυντικά στελέχη της εφοδιαστικής αλυσίδας (elite informants) 25 επιχειρήσεων

Εντοπίζουμε πώς η υιοθέτηση του DLT σε επίπεδο εφοδιαστικής αλυσίδας οδηγεί σε δραστηριότητες, προθέσεις και αποφάσεις που επηρεάζουν είτε άμεσα είτε έμμεσα το επιχειρηματικό μοντέλο του οργανισμού. Χαρτογραφούμε τις διαστάσεις του επιχειρηματικού μοντέλου που επηρεάζονται και παρέχουμε ένα μοντέλο ανάλυσης και αξιολόγησης των αποφάσεων που σχετίζονται με την υιοθέτηση του DLT σε επίεδο εφοδιαστικής αλυσίδας. Επιπλέον διαπιστώνουμε πως η υιοθέτηση του DLT οδηγεί σε αλλαγές των επιμέρους διαστάσεων του επιχειρηματικό μοντέλου της επιχείρησης.

Στην έρευνα μας αποδεχόμαστε την βασική θεώρηση, βάση βιβλιογραφίας, ότι η εμπιστοσύνη μεταξύ των αλληλοεπιδρώντων μερών είναι ο κύριος λόγος υιοθέτησης του DLT. Εστιάζουμε την έρευνά μας στα σημεία αλληλεπίδρασης του οργανισμού με τις οντότητες εκτός αυτού στο επίπεδο του επιχειρηματικού οικοσυστήματος στο οποίου λειτουργεί η επιχείρηση, προκειμένου να διερευνήσουμε πώς η υιοθέτηση DLT επηρεάζει το επιχειρηματικό της μοντέλο. Βάση των αποτελεσμάτων της έρευνας μας καταλήγουμε στο συμπέρασμα ότι είναι πολύ απλοϊκό να υποστηρίξουμε ότι η εμπιστοσύνη και η διάθεση δεδομένων αποτελούν τις μόνες έμμεσες επιδράσεις στο επιχειρηματικό μοντέλο ένεκα της εφαρμογής του DLT. Τα αποτελέσματα της έρευνας μας αποκάλυψαν ότι η επιλογή και η αντικατάσταση ενός εταίρου στην εφοδιαστική αλυσίδας, ο επανασχεδιασμός διαδικασιών και συναλλαγών, η δημιουργία νέας γνώσης, οι κανόνες και τα κίνητρα συνεργασίας μεταξύ των αλληλοεπιδρώντων μερών της εφοδιαστικής αλυσίδας επιδρούν στο επιχειρηματικό μοντέλο όταν η ανταλλαγή δεδομένων γίνεται μέσα από τη τεχνολογία του DLT. Τα αποτελέσματά της έρευνας μας δείχνουν ότι η υιοθέτηση του DLT ενεργοποιεί τον μετασχηματισμό της εμπιστοσύνης και της συνεργασίας της εφοδιαστικής αλυσίδας μεταξύ του οργανισμού και των διασυνδεδεμένων μερών της αλυσίδας εφοδιασμού σε επίπεδο οικοσυστήματος. Το μοντέλο απόφασης για την υιοθέτηση του DLT σε επίπεδο εφοδιαστικής αλυσίδας που αναπτύχθηκε βάση των αποτελεσμάτων της έρευνας, παρουσιάζει μια δυναμική εικόνα μιας ακολουθίας διαδικασιών αποτελούμενη από δραστηριότητες και προθέσεις που τελικά καταλήγουν υποδεικνύουν τις επιπτώσεις στις διαστάσεις του επιχειρηματικού μοντέλου.

Οι ισότιμες (εφεξής peer-to-peer) συναλλαγές μεταξύ των μελών του δικτύου, ο μεγάλος αριθμός συμμετεχόντων στο δίκτυο διασφαλίζουν τόσο την ασφάλεια της εφαρμογής του DLT όσο και την ανάγκη για θετικές συνέργειες-δικτύου (network effects). Επιπλέον υπογραμμίζουν την ανάγκη να αποδεχθούμε την προσέγγιση του επιχειρηματικού οικοσυστήματος ένεκα της εφαρμογής του DLT. Σε αυτό το πλαίσιο η αλληλοεπίδραση με DLT μεταξύ των φορέων δημιουργεί αξία για το οικοσύστημα και κατ' επέκταση για το κάθε αλληλοεπιδρών μέρος αυτού ξεχωριστά. Αυτή δημιουργία αξίας μπορεί να αφορά διαφορετικούς τύπους οικοσυστημάτων όπως οικοσυστήματα καινοτομίας, ψηφιακά , επιχειρηματικά κλπ.

Στην έρευνα μας διευκρινίζουμε ποιο τύπο οικοσυστήματος πρέπει να λάβουμε υπόψη όταν αναφερόμαστε σε ολιστική εφαρμογή του DLT στην αλυσίδα εφοδιασμού. Παρουσιάζουμε τις αναλογίες και ομοιότητες διαφορετικών τύπων οικοσυστημάτων με αυτό που δημιουργείται λόγω των αλληλεπιδράσεων των επιχειρήσεων μέσω της τεχνολογίας DLT. Υποστηρίζουμε ότι η οικονομική κοινότητα που αποτελείται από οργανισμούς, που αν και ανεξάρτητοι, συνδέονται και αλληλοεπιδρούν μεταξύ τους μέσω του DLT σχηματίζουν αυτό που στο εξής αποκαλούμε οικοσύστημα DLT. Η τεχνολογία DLT μπορεί να εφαρμοστεί σε πολλούς τύπους οικοσυστημάτων. Ωστόσο, λίγη έρευνα έχει γίνει για το πώς λειτουργεί το DLT σε όλους τους τύπους οικοσυστημάτων. Αναγνωρίζουμε συγκεκριμένα χαρακτηριστικά οικοσυστήματος – DLT και υποστηρίζουμε ότι υπάρχουν ομοιότητες μεταξύ των διαφόρων τύπων οικοσυστημάτων. Η έρευνα μας επεκτείνει τη βιβλιογραφία που σχετίζεται με τη μελέτη του DLT και των επιχειρηματικών οικοσυστημάτων απαντώντας στο ερευνητικό υπό-ερώτημα (subRQ1.1), συγκεκριμένα:

«Ποιες είναι οι αναλογίες των διάφορων τύπων οικοσυστημάτων με το DLT-οικοσύστημα ».

Βάση της θεώρησης του DLT ως μια καινοτόμος ψηφιακή τεχνολογία που προσδιορίζει τις συναλλαγές (transactions) μεταξύ των μελών του οικοσυστήματος, επιλέξαμε να εξετάσουμε τους τύπους των ψηφιακών οικοσυστημάτων, τεχνολογικών οικοσυστημάτων, οικοσυστήματα καινοτομίας, οικοσυστήματα προϊόντων και υπηρεσιών, ως είδη οικοσυστημάτων πιο κοντά στην έννοια και τη λογική λειτουργίας του οικοσυστήματος – DLT. Αποκαλύψαμε τις ομοιότητές τους με το τύπο του επιχειρηματικού οικοσυστήματος – DLT (DLT business ecosystem) και εντοπίσαμε τα βασικά χαρακτηριστικά που κάνουν τα παραπάνω είδη οικοσυστημάτων να αποκλίνουν από την προσέγγιση του επιχειρηματικού οικοσυστήματος – DLT. Από αυτή τη σύγκριση συμπεράνουμε ότι κάθε ένα από αυτά τα οικοσυστήματα μπορεί να αναπτυχθεί μέσα στο επιχειρηματικό οικοσύστημα - DLT. Τα επιμέρους οικοσυστήματα μπορεί επίσης να αποτελούν υποσύνολο του, χωρίς όμως αυτό να σημαίνει ότι πρέπει αναγκαστικά να ταιριάζουν με τα βασικά χαρακτηριστικά του οικοσυστήματος – DLT και δεν πληρούν τους στόχους του. Καταλήξαμε στο συμπέρασμα ότι το τελευταίο μπορεί να επιτευχθεί μόνο με την προσέγγιση του επιχειρηματικού οικοσυστήματος. Επομένως, απαντώντας στο ερευνητικό υπό-ερώτημα (subRQ1.1) σχετικά με το ποιος τύπος οικοσυστήματος είναι πιο κοντά στην έννοια του DLT, καταλήξαμε στην προσέγγιση του επιχειρηματικού οικοσυστήματος. Για να γίνει αυτό εμφανές, χαρτογραφήσαμε τις αναλογίες του επιχειρηματικού οικοσυστήματος με το οικοσύστημα DLT και εντοπίσαμε τις ομοιότητες μεταξύ αυτών των δύο εννοιών.

Υποστηρίζουμε ότι όταν διερευνούμε την υιοθέτηση DLT υπό το πρίσμα του οικοσυστήματος, πρέπει να λάβουμε υπόψη τους ρόλους που διαδραματίζουν οι φορείς του οικοσυστήματος ώστε να διασφαλίζεται η βιωσιμότητά του. Η αξία της εφαρμογής DLT έγκειται στη βιωσιμότητα του δικτύου DLT. Η αξία που δημιουργείται στο δίκτυο DLT, δηλαδή στο δίκτυο που σχηματίζεται από επιχειρήσεις που υιοθετούν και αλληλοεπιδρούν ολιστικά μέσω DLT, παράγεται συλλογικά από τα μέλη του. Με αυτόν τον τρόπο μπορούμε να διερευνήσουμε με μεγαλύτερη ακρίβεια τις αιτίες υιοθέτησης DLT, καθώς διαφορετικοί ρόλοι στο οικοσύστημα – DLT, εντός ενός εξαιρετικά δυναμικού περιβάλλοντος, οδηγούν σε διαφορετικά κίνητρα υιοθέτησης DLT από τους οργανισμούς που επιθυμούν να συμμετάσχουν σε αυτό. Βασιζόμενοι στα χαρακτηριστικά 'δικτύου' που από τη φύση τη επιβάλει η τεχνολογία DLT επεκτείνουμε την υπάρχουσα έρευνα απαντώντας στο δεύτερο ερευνητικό υπό-ερώτημα (subRQ1.2) συγκεκριμένα:

«Πώς οι φορείς του οικοσυστήματος – DLT με βάση τον ρόλο τους, συμβάλλουν στη βιωσιμότητα του;».

Ελάχιστη έρευνα έχει γίνει για το πώς ο ρόλος που κατέχει ο κάθε οργανισμός εντός ενός οικοσυστήματος - DLT επηρεάζει τη βιωσιμότητα του. Προς διερεύνηση του παραπάνω λαμβάνουμε υπόψη το δυναμικό περιβάλλον, εντός του οποίο λειτουργούν οι επιχειρήσεις, όπου η ανταλλαγή αξιόπιστων δεδομένων παίζει θεμελιώδη ρόλο στην επίτευξη της βιωσιμότητας του οικοσυστήματος – DLT.

Εντοπίσαμε ότι η αρχιτεκτονική DLT και οι ρόλοι των οντοτήτων του οικοσυστήματος είναι μείζονος σημασίας για τη βιωσιμότητά του. Η δύναμη και η στάση των κυρίαρχων παικτών του οικοσυστήματος ως εντός του οικοσυστήματος αποτελούν τους θεμελιώδεις πυλώνες της βιωσιμότητας του οικοσυστήματος – DLT. Οι «ήσσονος σημασίας» εταίροι (niche players), κατ' αναλογία με τη σχετική βιβλιογραφία ως προς τα 'επιχειρηματικά οικοσυστήματα (business ecosystems)', αποτελούν τη μη κυρίαρχη ομάδα φορέων στο οικοσύστημα – DLT. Η συμμετοχή τους σε αυτό συνδέεται με την προοπτική επέκτασής του , υπό την έννοια της συμμετοχής περισσότερων φορέων που προσδίδουν προοπτικές βιωσιμότητας του οικοσυστήματος. Υποστηρίξαμε ότι εάν οι «ήσσονος σημασίας» παίκτες του οικοσυστήματος αισθάνονται ότι απολαμβάνουν δυσανάλογη αξία σε σχέση με αυτή που δημιουργείται στο οικοσύστημα συνολικά, θα αποθαρρυνθούν να συμμετάσχουν σε αυτό, θα αποχωρήσουν ή «ήσσονος σημασίας» παίκτες δεν συνεχίσουν να συμμετέχουν σε αυτό και τελικά θα υπονομεύσουν τη βιωσιμότητα του. Είναι επομένως προφανές ότι η βαθιά έναντι της επιβαλλόμενης συνεργασίας μεταξύ των μερών του οικοσυστήματος – DLT είναι απαραίτητη προϋπόθεση για την επιβίωση τους. Ως εκ τούτου κοινή μοίρα που συνδέει όλων τους συμμετέχοντες στο οικοσύστημα – DLT πρέπει να ωθεί τους κυρίαρχοι παράγοντες του οικοσυστήματος – DLT που ορίζουν τη δομή και τη μορφή του πρέπει να πιέσουν προς αυτή την κατεύθυνση.

Στην έρευνά μας εξερευνήσαμε τη δυναμική του οικοσυστήματος – DLT και υπό αυτό το πρίσμα προσδιορίσαμε ότι η ισορροπία του οικοσυστήματος, η ευρωστία, η παραγωγικότητα, η συμμετοχή «ήσσονος σημασίας» παικτών σε αυτό, η επεκτασιμότητα του, η ευελιξία, η ευθυγράμμιση του στόχου συμμετοχής από όλους τους συμμετέχοντες καθώς και οι δραστηριότητες και η αλληλεξάρτηση τους αποτελούν παράγοντες βιωσιμότητας του οικοσυστήματος - DLT. Παρουσιάζουμε τις ενδογενείς και εξωγενείς δυνάμεις που επηρεάζουν την εξέλιξη του οικοσυστήματος – DLT . Υποστηρίζουμε ότι η συν εξέλιξη που βασίζεται στη μεταφορά γνώσης και πόρων, την επιλεγμένη αρχιτεκτονική του DLT, τους τύπους σχέσεων που αναπτύσσονται ιδιαίτερα σε ότι αφορά του «ήσσονος σημασίας» παίκτες και οι αλλαγές ρόλων σε ένα εξαιρετικά δυναμικό περιβάλλον οικοσυστήματος, αποτελούν τους κύριους ενδογενείς παράγοντες επιτυχίας στην γενικότερη εξέλιξη του οικοσυστήματος – DLT. Από την άλλη πλευρά, οι αλλαγές της αγοράς, οι αλλαγές στο οικονομικό και κοινωνικό περιβάλλον, οι τεχνολογικές αλλαγές και οι κανονισμοί θεωρήθηκε ότι αποτελούν τους αντίστοιχους εξωγενείς παράγοντες.

Με βάση τις πιο πρόσφατες εξελίξεις ως προς τις εφαρμογές του DLT, προσδιορίζουμε τη δυναμική του οικοσυστήματος σχετικά με τον τύπο του επιχειρηματικού οικοσυστήματος- DLT, όπως προσδιορίστηκε κατά την απάντηση στο πρώτο ερευνητικό υπό-ερώτημα (subRQ1.1) και προτείνουμε τους παράγοντες που πρέπει να ληφθούν υπόψη για τη βιωσιμότητά του. Υπό αυτή την προϋπόθεση, δίνουμε έμφαση στις θετικές συνέργειες σε επίπεδο δικτύου (network effects) που δημιουργούνται εντός του οικοσυστήματος ανάλογα με την κυρίαρχη ή μη θέση του κάθε οργανισμού σε αυτό. Για να αποκτήσουμε πλήρη εικόνα της υιοθέτησης DLT στην εφοδιαστική αλυσίδα, επεκτείνουμε την έρευνά μας πέρα από τη προφανή αλληλεπίδραση της εφοδιαστικής αλυσίδας του οργανισμού με άλλους οργανισμούς, όπως απαντήθηκε από το πρώτο κύριο ερευνητικό ερώτημα (mRQ1).

Θεωρούμε ότι πρέπει επίσης να κοιτάξουμε εσωτερικά στον οργανισμό για τη διερεύνηση των αιτιών υιοθέτησης DLT σε διεργασίες που αφορούν αποκλειστικά τις εσωτερικές διαδικασίες και αλληλεπιδράσεις των τμημάτων της αλυσίδας εφοδιασμού της επιχείρησης To DLT ένεκα των ενδογενών χαρακτηριστικών δικτύου (network facet) που το χαρακτηρίζουν δεν φαίνεται, τουλάχιστον εκ πρώτης όψεως, να υπόσχεται σημαντικά οφέλη εξετάζοντάς την εφαρμογή του αποκλειστικά υπό το πρίσμα των εσωτερικών διαδικασιών της αλυσίδας εφοδιασμού ενός οργανισμού. Σε αυτό το μέρος της έρευνάς μας, αρχικά διερευνούμε εάν τα εσωτερικά σημεία επαφής μεταξύ των αλληλοεπιδρώντων μερών εσωτερικά στην εφοδιαστική αλυσίδας παρέχουν πρόσφορο έδαφος για την αξιοποίηση των πλεονεκτημάτων του DLT, απαντώντας έτσι στο δεύτερο κύριο ερευνητικό ερώτημα (mRQ2), συγκεκριμένα:

«Πώς οι αιτίες υιοθέτησης DLT σε επίπεδο εσωτερικής αλυσίδας εφοδιασμού επηρεάζουν το επιχειρηματικό μοντέλο του οργανισμού;».

Έρευνα: Ακολουθήθηκε η μεθοδολογία της επαγωγικής ποιοτικής έρευνας μεμονωμένης περίπτωσης (single case study qualitative inductive research) . Η μεμονωμένη περίπτωση επιλέχθηκε βάση συγκεκριμένων χαρακτηριστικών του οργανισμού τα οποία δεν παρέχουν προφανή λόγο εφαρμογής της τεχνολογίας DLT εντός της εφοδιαστικής αλυσίδας. Η συλλογή δεδομένων έγινε μέσα από 4 γύρους ημι-δομημένων συνεντεύξεων με διευθυντικά στελέχη της εφοδιαστικής αλυσίδας του οργανισμού (elite informants). Συνεντεύξεις από 12 στελέχη μιας μονάδας παρείχαν τα αρχικά δεδομένα προς ανάλυση τα οποία μετά την επεξεργασία τους επιβεβαιώθηκαν από 2 ανώτερα στελέχη της εφοδιαστικής αλυσίδας 3 επιπλέον μονάδων παραγωγής που ανήκουν στο ίδιο όμιλο επιχειρήσεων και παράγουν παρόμοια προϊόντα

Βασίσαμε αυτό το μέρος της έρευνά μας σε προσεκτικά επιλεγμένη ποιοτική επαγωγική έρευνα μεμονωμένης περίπτωσης (single case study) που αφορά μια πολυεθνική επιχείρηση κατασκευής οικιακού εξοπλισμού (home appliance original equipment global manufacturer – 'HA-OEM'). Για να κατανοήσουμε σε ποιο βαθμό το επιχειρηματικό μοντέλο της επιχείρησης επηρεάζεται από την εφαρμογή DLT υπό το πρίσμα και μόνο των εσωτερικών διαδικασιών της αλυσίδας εφοδιασμού, αρχικά αναλύουμε τις κύριες διαστάσεις του επιχειρηματικού μοντέλου και αξιολογούμε πώς επηρεάζεται κάθε μια από αυτές. Κατόπιν πλήρης καταγραφή των διαδικασιών και αποφάσεων που οδηγούν στην απόφαση υιοθέτησης DLT, σε επίπεδο εσωτερικών διαδικασιών εσωτερικής αλυσίδας εφοδιασμού, απεικονίζουμε το σχετικό μοντέλο απόφασης, Το μοντέλο απεικονίζει τις δυναμικές σχέσεις μεταξύ των βασικών αιτιών υιοθέτησης DLT για τις εσωτερικές και μόνο διαδικασίες της εφοδιαστικές αλυσίδας και επιπλέον απεικονίζει την επίδρασή τους του στο επιχειρηματικό μοντέλο του οργανισμού.

Για να αξιολογήσουμε τον αντίκτυπο που έχει στο επιχειρηματικό μοντέλο η υιοθέτηση DLT στις εσωτερικές λειτουργίες της αλυσίδας εφοδιασμού, επιλέχθηκε η χρήση της αρχιτεκτονικής επιχειρηματικού μοντέλου που προτείνεται από τον Velu (2018). Το μοντέλο αυτό αρχικά συμπεριλαμβάνει τις πλέον κοινά αποδεκτές από τη βιβλιογραφία διαστάσεις επιχειρηματικού μοντέλου. Δηλαδή, τις διαστάσεις της δημιουργία αξίας (value creation), την πρόταση αξίας (value proposition), τη σύλληψη αξίας (value capture). Επιπλέον όμως προσθέτει τη διάσταση της αξίας του δικτύου (value network) που συνάδει με τα χαρακτηριστικά της τεχνολογίας DLT. Η παρούσα έρευνα αποκάλυψε ότι η ύπαρξη 'ασυμμετρίας πληροφοριών (information asymmetry)' έχει το μεγαλύτερο αντίκτυπο στο μετασχηματισμό του επιχειρηματικό μοντέλο κατόπιν υιοθέτησης του DLT. Δεδομένου ότι οι εσωτερικές λειτουργίες της αλυσίδας εφοδιασμού αναφέρονται κυρίως στη διαμόρφωση του προϊόντος και εν γένη σε διαδικασίες σχετιζόμενες με την παραγωγή, η διάσταση του επιχειρηματικού μοντέλου που αφορά τη 'δημιουργία αξίας' διαπιστώθηκε ότι είναι η διάσταση που επηρεάζεται περισσότερο, όπως αναμενόταν άλλωστε, ακολουθούμενη από αυτή του 'δικτύου αξίας'.

Τα αποτελέσματα της έρευνάς μας δείχνουν ότι μεταξύ εταιρειών που ενσωματώνουν make-to-order (MTO) γραμμές παραγωγής, η πρόθεση των τμημάτων της εφοδιαστικής αλυσίδας να αλληλό-εμπιστεύονται διαδικασίες και δεδομένα δεν είναι στατική. Αυτή μεταβάλλεται βάση της διαμορφούμενης κάθε φορά σχέσης εμπιστοσύνης ανάμεσα στα διασυνδεδεμένα μέρη της αλυσίδας εφοδιασμού. Η ικανότητα (capability) και η ακεραιότητα (integrity) που είναι, βάση βιβλιογραφίας, από τις πιο ευρέως αναγνωρισμένες διαστάσεις των μοντέλων «εμπιστοσύνης» σε ένα οργανισμό», αποτελούν τις βασικές παραμέτρους αποτύπωσης του επιπέδου εμπιστοσύνης που επιτυγχάνεται μέσω της συνεργασίας των τμημάτων της εφοδιαστικής αλυσίδας και των αλληλεπιδράσεων με οντότητες εσωτερικά και εξωτερικά αυτού. Τα ερευνητικά μας αποτελέσματα έδειξαν ότι στις αποτελεσματικές αλυσίδες εφοδιασμού υπάρχει ισχυρή εμπιστοσύνη μεταξύ εσωτερικών και εξωτερικών μερών της εφοδιαστικής αλυσίδας. Ωστόσο, ο ανταγωνισμός μεταξύ των όλων αλληλοεπιδρώντων μερών του οικοσυστήματος – DLT συνήθως παραμένει. Καταδείχθηκε ότι σε μια καλά δομημένη αλυσίδα εφοδιασμού, η μοναδική πηγή αλήθειας, όπως υπόσχεται η τεχνολογία DLT, θα πρέπει να είναι σε θέση να εκθέσει την όποια ανταγωνιστική συμπεριφορά υπονομεύει τη λειτουργική αποτελεσματικότητα της εσωτερικής αλυσίδας εφοδιασμού. Η συλλογή και καταγραφή δεδομένων μέσω σύγχρονων ολοκληρωμένων πληροφοριακών συστημάτων ενισχύει τη λήψη αποφάσεων βάσει δεδομένων (data driven decision making). Παρ ’όλα αυτά, τα κενά στα αρχεία δεδομένων που παρουσιάζονται ως προς την καταγραφή όλων των δεδομένων που αφορούν την εφοδιαστική αλυσίδα, η ενδεχόμενη αναποτελεσματικότητα στην ανταλλαγή πληροφοριών, οι έλεγχοι (audits) που καταναλώνουν πόρους της επιχείρησης και η εμφανιζόμενες αστοχίες ανταλλαγής πληροφοριών σε «σχεδόν» πραγματικό χρόνο (near real time), αποτελούν αιτίες που οδηγούν σε αναποτελεσματικές αποφάσεις και προκαλούν ανεπάρκειες ως προς τη δια-τμηματική συνεργασία εντός του οργανισμού.

Όσον αφορά τις πληροφορίες που καταγράφονται και κοινοποιούνται εσωτερικά στην επιχείρηση, η έρευνα αποκάλυψε αναποτελεσματικότητα στις διαδικασίες εξόρυξης και ανταλλαγής δεδομένων. Προβλήματα που σχετίζονται με εμπόδια (bottlenecks) στη ροή ανάλυσης των πληροφοριών που λαμβάνονται ως feedback από τους πελάτες, αξιόπιστα δεδομένα προγραμματισμού παραγωγής που απαιτούνται για αναθεωρήσεις του πλάνου παραγωγής όποτε αυτό απαιτείται, συγχρονισμός δεδομένων μεταξύ γραμμών παραγωγής, ζητήματα δια-τμηματικής συνεργασίας και αναποτελεσματικότητα εσωτερικής επικοινωνίας λόγω εσφαλμένων αντιλήψεων ή καθυστερήσεων στην αντιστοίχιση δεδομένων, αποκάλυψαν ασυμμετρίες στο επίπεδο διαχείρισης και πρόσβασης στα δεδομένα της εφοδιαστικής αλυσίδας (effort-level information asymmetries). Τα ευρήματα της έρευνας υπογράμμισαν τη σημασία των μηχανισμών διαμοιρασμού (sharing) και ανταλλαγής (exchange) πληροφοριών μεταξύ των τμημάτων της εταιρείας και ιδιαίτερα εκείνων που σχετίζονται με τον προγραμματισμό παραγωγής, τη διαχείριση αποθεμάτων και τον έλεγχο παραγωγής. Ο ρόλος του DLT συνάδει με τον ρόλο ενός μηχανισμού, ο οποίος διασφαλίζει ότι οι αρμόδιοι αλληλοεπιδρώντες φορείς της εφοδιαστικής αλυσίδας θα εκτελούν τα καθήκοντά τους σύμφωνα με τα προκαθορισμένα πρότυπα. Με την απόκτηση εμπειρίας, οι εταιρείες γίνονται πιο ικανές καθώς βελτιώνουν ορισμένες δεξιότητες και αποκτούν μεγαλύτερη γνώση. Η ολιστική εφαρμογή DLT στην εφοδιαστική αλυσίδα ενισχύει το άνοιγμα των δεδομένων, τη πρόσβαση από πολλά μέρη στα ίδια δεδομένα και τη διαφάνεια των δεδομένα εσωτερικά στην εφοδιαστική αλυσίδα ενός οργανισμού. Επιπλέον μειώνει την ασυμμετρία στη διαχείριση και πρόσβαση σε δεδομένα (information asymmetries), από τα μέρη της εφοδιαστική αλυσίδας που αλληλοεπιδρούν ωθώντας τα να αναβαθμίσουν τις ικανότητές τους.

Ελλείψει ερευνών σχετικά με τον τρόπο με τον οποίο η υιοθέτηση DLT σε επίπεδο εσωτερικής εφοδιαστικής αλυσίδας θα μπορούσε να επηρεάσει τη λιτότητα της παραγωγής (manufacturing leanness), βασιζόμαστε στα ευρήματα του mRQ2 για να απαντήσουμε ένα επιπλέον ερευνητικό υπό-ερώτημα (subRQ2.1), δηλαδή :

«Σε ποιο βαθμό η υιοθέτηση DLT επηρεάζει τη λιτότητα της παραγωγής (manufacturing leanness);»

Από τα στελέχη και εργαζόμενους της επιχείρησης HA-OEM που συμμετείχαν στις συνεντεύξεις για συλλογή δεδομένων με σκοπό την απάντηση στο mRQ2, συλλέγουμε και αναλύουμε εκ νέου δεδομένα βασιζόμενοι την υπόθεση ότι η υιοθέτηση του DLT θα επηρεάσει μόνο τη ροή πληροφοριών και δεν θα ληφθεί υπόψη καμία άλλη τεχνική βελτίωσης της ροής υλικού. Χρησιμοποιούμε τη μεθοδολογία χαρτογράφησης ροής της αξίας (value stream mapping – VSM) για να απεικονίσουμε την προσομοιωμένη μελλοντική κατάσταση σύμφωνα με τις υποθέσεις μας. Χρησιμοποιούμε δηλαδή τα αποτελέσματα από το mRQ2 για να εντοπίσουμε σε ποια σημεία της ροής της παραγωγής θα είχε επίδραση η εφαρμογή του DLT. Τελικά απεικονίζουμε και αξιολογούμε ποιες ροές παραγωγής (manufacturing streams) και σε ποιο βαθμό επηρεάζεται ο χρόνος διεκπεραίωσης των ροών παραγωγής (throughput time – TT). Με βάση τα ευρήματά μας, οκτώ (8) από τις δεκατρείς (13) ροές παραγωγής εμφάνισαν μειωμένο TT κατά 0,61% - 3,81%, λόγω υιοθέτησης του DLT. Η μείωση οφείλεται κυρίως στη μείωση των ενδιάμεσων αποθεμάτων (work-in-progress inventories) ένεκα της βελτίωσης της συνολικής αποτελεσματικότητας του εξοπλισμού (overall equipment effectiveness-OEE) που τα επηρεάζει. Επιπλέον διαπιστώθηκε ότι ενώ το συνολικό TT καθώς και η κρίσιμη ροή παραγωγής που το προσδιορίζει παραμείναν αμετάβλητα. Συνοψίζοντάς διαπιστώνουμε ότι η προστιθέμενη αξία στις εσωτερικές λειτουργίες της εφοδιαστικής αλυσίδας, λόγω της υιοθέτησης του DLT, αποκαλύπτει ότι το DLT δεν πρέπει να εκλαμβάνεται αποκλειστικά ως μια αυτόνομη λύση προς βελτιστοποίηση της εφοδιαστικής αλυσίδας. Αν και επιδείχθηκε ότι η εφαρμογή του DLT μπορεί συνεισφέρει και ως μια ακόμη μέθοδο βελτιστοποίηση, παρόλα αυτά η εφαρμογή της πρέπει να υπολογίζεται ως συνδυασμός με άλλα συστήματα ή διαδικασίες κοινής χρήσης δεδομένων που ήδη εφαρμόζει η επιχείρηση.

Contents

List of Figures and Tables

List of Abbreviations

BTO	buy-to-order
CONWIP	constant work in process
CT	cycle time
dApp	decentralized Applications
DAM	digital asset management
DD	delivery date
DLT	distributed ledger technology
ERP	enterprise resource planning
ETO	engineer-to-order
GFS	general flow shop
HA-OEM	home appliance original equipment manufacturer
JIT	just in time
LE	large enterprise
LT	Lead time
mRQ1	1st main research question
mRQ2	2nd main research question
MTO	make-to-order
MTS	make-to-stock
MRP	material resource planning
OPP	order penetration point
PIM	product information management
POLCA	paired cell overlapping loops of cards with authorization
POS	proof-of-stake
POW	proof-of-work
PPC	production planning and control
PT	process time
RBC	repeat business customizers
SCM	supply chain management
S/M	supermarket lean improvement process
SFTT	shop floor throughput times
SLA	service level agreement
SME	small-medium enterprise
STS	ship-to-stock
TT	throughput time
TOC	theory of constraints
subRQ1.1	sub research question 1 for main research question 1
subRQ1.2	sub research question 2 for main research question 1
subRQ2.1	sub research question 1 for main research question 2
TPS	Toyota production system
TPM	total preventive maintenance
OEE	overall equipment effectiveness
VMC	versatile manufacturing companies
VSM	value stream mapping
WIP	work in progress
WLC	work load control

1. Introduction

[1]*Digitalization affects almost everything in today's organizations, including the way that supply chains collaborate and puts pressure for change. Digitalization of intra and inter-organizational processes reveals new avenues of transformation in operations and supply chain management (Holmström, J. et al. 2019). Distributed Ledger Technology (DLT), or else blockchain, promises a new path of digitalization through the decentralized way that companies interact and exchange data. The latter pushes companies to rethink the way they design and operate their supply chains. Being a foundational rather than a disruptive technology, DLT does not attack the traditional business model but offers multiple opportunities to innovate it (Weking, J. et al. 2020; Iansiti and Lakhani, 2017).* In today's globalized economy, supply chain operations effectiveness and efficiency depend upon the synchronization and coordination not only of the internal to company processes and departments but also of the external to the organization entities, that intersect with in-house supply chain operations.

We acknowledge trust among interacting parties and the need for disintermediation as the main DLT adoption drivers. In our research we focus on the intersection of organization's supply chain with entities external and internal to the company. We adopt a qualitative case study approach, to answer two primary research questions. The first (mRQ1) is: "What are the implicit effects in business model that stem from DLT adoption?" That question will be answered through a multiple case study research, which focuses on organization's supply chain interactions with entities external to the organization. The second main research question (mRQ2) is "How DLT adoption causations at in-house supply chain level impact organization's business model?" This question will be answered based on a single case study research, selected through specific criteria that fit to research purpose. Case study focuses both on DLT interactions among in-house supply chain entities. Recognizing the impact of supply chain transformation into manufacturer's business model, we intend to reveal how DLT adoption could impact organization's business model through the respective supply chain transformations triggered. We seek to reveal in-house supply chain DLT adoption

---

[1] Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

causations by investigating organization's processes intersections internally and externally to its supply chain. Based on the conclusions drawn we describe their impact on business model dimensions. Based on the findings of mRQ2 we will further investigate the impact of DLT adoption at in-house supply chain level to manufacturing leanness thus answering the research sub question (subRQ2.1) of "To what extend could DLT adoption impact manufacturing leanness". We will extend data collection through the participants and elite informants engaged in single case study data collection for the purpose of answering the mRQ2.

We start Chapter 1 by introducing DLT. We refer to how DLT works considering its types, architectures and benefits as well as the main DLT developments such as dApps and smart contracts that allow DLT adoption diffusion. Based on DLT traits and attributes we argue for an ecosystem approach and beyond that we refer to DLT ecosystem sustainability. We pay special attention to the network effects created within the DLT ecosystem since they are necessary for its expansion. We further investigate the DLT ecosystem dynamics developed. Given the fact that to investigate DLT ecosystem we need to dive deeper in ecosystem literature, we explore how ecosystem types make fit to DLT. In that sense we introduce the first sub research question (subRQ1.1), which is "How do ecosystem types make fit to DLT?". We argue that shared fate of DLT ecosystem, requires each member, irrespective of its position in it, to have a clear perception of the expected business value and the value that will be shared with other ecosystem entities. Shared fate of ecosystem interacting actors leads to explore the aspects of DLT ecosystem sustainability. Thus, before we explore business model effects by DLT adoption we insert another research sub question (subRQ1.2), which is "What are the Business Ecosystem actor roles for DLT ecosystem sustainability" to identify the aspects of DLT ecosystem sustainability.

In Chapter 2 we refer to the theoretical background that supports our research. We dive deeper into the business ecosystem perspective, thus exploring its definitions, enablers and the evolution from inter-firm relations. To identify the ecosystem type that fits to DLT we refer to ecosystem conceptualizations, that based on literature, are closer to DLT ecosystem approach. Based on literature we explore the attributes of software, technological, digital service, product and innovation ecosystem types. Moreover, we investigate DLT ecosystem sustainability, ecosystem dynamics, actor roles, endogenous and exogenous forces of ecosystem evolution. Moreover, in Chapter 2 we introduce the business model theory, elaborate on how it is related to organization strategy and refer to business model innovation. Since the focus of our research is DLT adoption under the supply chain context, we refer to DLT interconnected supply chains. We explicitly consider the notion of trust, as one of the key DLT adoption drivers, thus probing into how it is related to manufacturing in-house supply chain operations. In that we way we lay the theoretical background of answering the mRQ2.

In Chapter 3 we present the methodology that will be followed to answer the two main research questions mRQ1 and mRQ2. Since we selected qualitative inductive case study approach, we present in detail all the parameters that affected case study empirical setting. We present data collection efforts, data analysis set up and results along with the strategy followed to ensure data trustworthiness. For mRQ1, we selected multiple case study approach. mRQ2 a single case study approach has been adopted. For the latter we present the single case study selection criteria and how does the selected case meet them. Moreover, in Chapter 3 we present the methodology, data collection, data analysis efforts that will be taken to answer the subRQ2.1 We elaborate on the results of mRQ2 and perform a new round of data collected at shop floor level through the same single case study as in mRQ2, analyzed and presented through the value stream mapping (VSM) method.

In Chapter 4 we present the findings that emerged from data structure created after data analysis, as described in Chapter 3, For the first main research question (mRQ1), we describe ten (10) overarching themes that have been inductively identified after multiple case study analysis. Based on data analysis related to the second main research question (mRQ2) we present five (5) overarching themes. We analyze how those themes have been emerged based on the qualitative analysis and coding followed and what are the links between different layers of the coding structure followed. For the subRQ2.1 we depict the impact on DLT adoption to manufacturing leanness. Based on our simulation, eight (8) out of thirteen (13) manufacturing streams demonstrated reduced TT by 0,61% to 3,81%, due to DLT adoption, while the total TT as well as the critical manufacturing stream have been found to remain unchanged.

In Chapter 5 we quote all research conclusions. We initially refer to the conclusions stemmed by the two research sub-questions that answer, “How do ecosystem types make fit to DLT” (subRQ1.1) and “How DLT ecosystem actor based on their role, contribute to ecosystem sustainability” (subRQ1.2). Based on the findings presented in Chapter 4 we propose a process model that incorporates implicit business model effects of DLT adoption, under a manufacturing supply chain context. We discuss how DLT adoption for a manufacturer leads to activities and decisions which affect its business model. Respectively for subRQ1.2 we develop a process model to assess the factors that resonate DLT adoption at in-house supply chain level. Beyond that we discuss its impact on re- shaping the business model dimensions. Regarding the subRQ2.1we discuss the limited impact of DLT to manufacturing leanness, that is mainly based on the potential overall equipment effectiveness (OEE) improvements. We also present the impact of DLT adoption under the case of unexpected PPC disruptions, unexpected manufacturing SLA deviations or decisions that are related to production planning and not affected by OEE. Research flow process for all main and sub research questions is illustrated in Figure 1

In Chapter 6 we discuss research managerial implications and limitations. We further elaborate on how through the process models proposed, managers could assess DLT impact on business model based on the implications triggered by DLT adoption. Moreover, we exact conclusions on how DLT adoption managerial decisions could be assisted through the degree that DLT fulfill any supply chain inefficiencies stemmed by the absence of enhanced trust and disintermediation. Limitations presented oi Chapter 6 are referring to the respective multi and single case study selection criteria, such organization size, manufacturing type and manufacturing strategies.

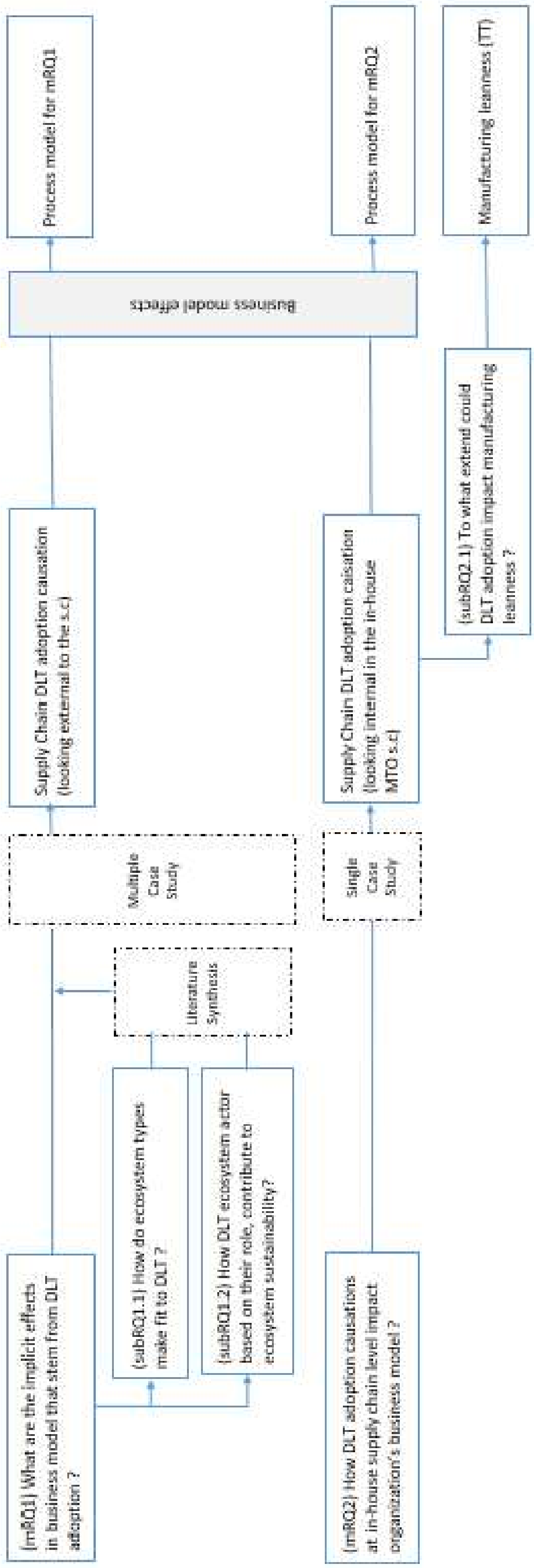


Figure 1 Research flow process

1.1 What is DLT and how it works.

DLT is essentially the technology that allows the decentralized storage of totally ordered records or digital events grouped into blocks. DLT network participants invoke cryptographically protected transactions to transfer virtual assets between their accounts. Each transaction is digitally signed by the issuer and posted to the ledger. Transaction has to be approved by competing nodes before it gets committed by the DLT network. To initiate this process, transaction is broadcasted to every node in the network. Those nodes will collect transactions into a block, verify them in the block and broadcast the block and its respective verification using a consensus mechanism to get approval from the network (Zhang, Xue and Ling, 2019). Every time a new block is created, it is broadcasted to all DLT network members that add it in chronological order to their local copy of ledger. Consensus mechanism takes over to validate transactions and link blocks in a chronological order. Consensus mechanism is the method used among blockchain members to reach an agreement that information is valid and can be committed to the chain. The protocol that solves the consensus problem guarantees that blocks are totally ordered. Hence, preventing a block from being appended if it contains transactions that conflict with transactions of the previous block (Nicta,V.G. 2016). Furthermore, the more mature the block, e.g., the longer it has been in the ledger chain, the greater its integrity (Haoyan, W et al., 2017).

DLT allows the creation of a peer-to-peer network, where each participant holds a copy of the shared ledger of digital signed transactions. This sequence of linked historical transactions is referred to as chain, see Figure 2, and the evolved data structure is often referred as blockchain. In literature blockchain refers both to the entire technology and the implementing factors. In some cases, it is referred only to public DLT platforms. Since each DLT network participant holds an identical database or single version of information validated through consensus, it is affirmed that within DLT networks a single version of the truth is created. When interactions or transactions rely on a central trusted authority there is the risk that the single information provider doesn't tell the truth. DLT changes that due to the transparency promised, since entire events history access and consensus mechanism allow only the execution of valid transactions.

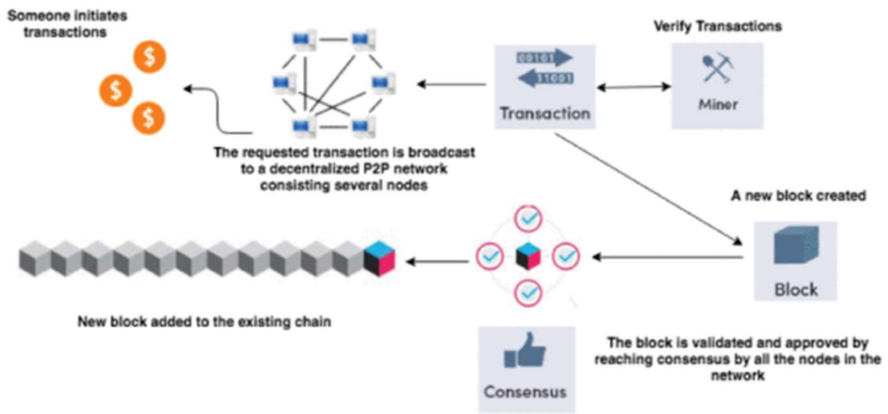


Figure 2: Functional diagram of blockchain network (Monrar, Selen and Andersson, 2019)

1.2 DLT evolution, smart contracts and dApps

Distributed databases concept is not new. Oracle released a distributed database system in 1985 (Oracle, 2017). DLT differs in the fact that database is managed uniquely decentralized, while Oracle's system and other distributed databases that followed, are managed by one central controlling entity. In DLT it is the stakeholders over the network that execute and control all three main database activities, meaning read, write and validate. Only after digital record is validated it becomes part of the network of transactions. DLT evolution can be summarized in four stages (Angelis and Ribeiro da Silva., 2019). Following the chronological evolution of DLT, in stage one DLT spotlight felled on the transactions and more specifically in applications related to cryptocurrencies and peer-to-peer transactions, without the need of trusted intermediaries. In the second stage, DLT had been extended to address privacy challenges and the idea of a programmable DLT came up. Smart contracts and Ethereum, the DLT platform that runs smart contracts, had been introduced in 2015 and are considered as a milestone in this evolution. Smart contract is a set of computer program code stored in DLT blocks that is self-executed when predetermined terms and conditions are met. Smart contracts are increasingly becoming the cornerstone for enterprise DLT applications. The pre-programmed terms of an agreement between two anonymous parties enable them to trade and do business. They enforce some type of agreement so that all participants can be certain of the outcome without the need for a middleman (Salviotti, et al., 2018).

Development of decentralized applications (dApp) fostered DLT transformation to the third stage of its evolution. dApps has its backend running on a decentralized peer-to-peer network, operate autonomously with no entity controlling the majority of its tokens. Its frontend code is written in any program language and makes calls to its backend. Although a bit premature to clearly define what Blockchain 4.0 will actually be, it seems that it will be an expansion of DLT focus to further incorporate improvements through Artificial Intelligence (AI). Although all DLT stages of development had different purpose and value drivers, as summarized in Table 1, they enabled new ways of value creation sparking the potential to build a foundation for creating unprecedented ecosystems (Iansiti and Lakhani,2017).

	Enablers	**Value Driver**
Blockchain 1.0	Decentralized Consensus	Transaction cost
Blockchain 2.0	Smart contracts	Added services
Blockchain 3.0	Decentralized applications, storage and computing	Organization boundaries
Blockchain 4.0	Decentralized artificial intelligence	Autonomous decision making

Table 1: Enablers and value drivers of blockchain (Tsatsou, et al., 2010)

1.3 DLT types and architecture

There is a o lot of hype around DLT architecture classification. Under one approach those architectures can be classified along three dimensions: (1) centralized versus decentralized, (2) private/ permissioned versus open/public and (3) on-chain versus off chain data storage (Xu, X., et al.,2017). Although designed for distributed architecture, DLT can be also implemented on centralized architecture, such as the permissioned DLT infrastructure offered by International Business Machines (IBM) for end-to-end supply chain management (IBM., 2017). Respectively, there are ecosystems developed around public, permissionless but distributed DLT architecture, such as the international shipping cargo freight solution Blockfreight (Smith, 2016). It is fact that the most popular DLT architectures, such as those implemented in Ethereum, are permissionless and public. On the contrary, privacy is usually combined with permissioned DLT architecture, that addresses the need of not disclosing to the public sensitive information

(Treiblmaier and Beck, 2019). According to a report published by the McKinsey & Co (2019) DLT architecture can be public and permissioned. In that format, anyone can join and read but only authorized participants can write and commit permissions. We will further breakdown the second dimension, into two more options (2i and 2i). 2i denotes the alternative where the architecture is based on data infrastructure ownership and is characterized as public, private or consortium. Consortiums are special -purpose DLT networks, where data can be private or public but only verified participants are allowed to validate blocks. Linux Foundation project Hyperledger is an example of such a network. The 2ii dimension underlines the permissioned / permissionless option, that defines DLT architecture based on read, write or commit permissions to the participants (Buterin, 2015).

Off chain data storage architecture addresses the need of data storage separately from the ledger for sensitive data, e.g., on cloud. Requests for access are posted on a public ledger and consensus mechanisms after verifying the validity of requests, post them to a private ledger for traceability purposes (Haoyan, et al. 2017). Recently there have been proposed various DLT designs, such as the two-way peg, lightning network, sidechains, plasma etc., in an effort to connect DLT networks together and increase scalability by overcoming on-chain DLT architecture barriers such as capacity issues. Creating programmatic connections and protocols between DLT, networks aim to facilitate value transfer between different ecosystem actors, resolve privacy concerns, increase dApps interoperability and gradually remove DLT mass adoption barriers.

1.4 Current projects, benefits, challenges and concerns.

DLT demonstrates significant potential and prospects for applications in a variety of economic fields. Organizations that already invest in DLT, apart from the financial sector belong in the technology media and telecom, manufacturing and energy and resources sector, based on Deloitte's 2019 global blockchain survey. Based on that survey, data access, sharing, validation and id protection are the foremost use cases among all industries. Although each industry pursues DLT in a way that best serves its collective interests and attacks its fundamental business challenges, all efforts try to prove the potential of capitalizing on the key DLT advantages of transparency traceability, advanced security, anonymity, trust and decentralization. Transparency, that refers to the access of the entire events history by all participants. Traceability, that relies on transparency, and refers to the opportunity of each DLT actor to trace goods along their supply chain route. Advanced security, that refers to the transaction immutability and their attribute that data can neither be eliminated nor counterfeited. Anonymity, that refers to the option not to disclose actors' identity in DLT operations. Trust, that refers to the opportunity of DLT network members with no established relationship to transact with high degree of confidence based on digital records available in the DLT network. Decentralization, that refers to the removal of middlemen and its profound impact on the cost saving aspect of business operations.

As expected for every technology in its primitive stage of development, there are some major concerns and fundamental technical challenges to be met, that undermine large-scale adoption of the technology. The same applies for DLT, irrespective of the industry applied. High level of computational power required to confirm DLT blocks, especially when proof-of-work (POW) consensus mechanism is adopted and the respective energy consumption, especially for public DLT networks, address the high-cost problem of DLT implementation (Yli-Huumo, J. D. et al. 2016; Fernandez-Carames and Fraga-Lamas, 2016). Storage capacity is another DLT technical concern. stemmed by the DLT security attributed regarding the large number of full nodes in DLT network required to validate transactions for each block (Reyna, et al.,2018). In addition to that, scalability is being affected negatively by the size of data exchanged through DLT, the transaction processing rate and the latency of data transmission (Koteska, et al, 2017). Apart from technical challenges, where progress is underway, there are concerns around the attitude and intentions of DLT actors due to dynamics developed in the respective ecosystem. Regulation concerns, such as who sets the standards in a DLT network and what should be the integration with legacy systems, are to be explored per industry considering the selected DLT architecture. The same applies to concerns that rely on DLT ecosystem actors' intention to participate in the network. The way that data are accessed and validated offer an undisputable value but there is skepticism around which pieces of information should be revealed in transactions. These concerns along with trust and power dynamics in DLT ecosystem, where data management and info sharing lay at the center of ecosystem value co-creation, will be further explored and treated in this study as the critical dimensions of ecosystem sustainability.

1.5 Network effect in DLT ecosystem and its impact on ecosystem expansion

Number of DLT ecosystem actors is crucial for network security. This is validated by the need of really high hashing power for one or more attackers to come out with 51% attack of any major DLT ecosystem. Moreover, in POW consensus mechanisms self-mining actors need more than 1/3 of the total mining power to gain outsized profits. In proof-of-stake (POS) consensus mechanisms, security comes from putting up economic value at loss. That among others means that the more the DLT network actors, the higher the stake for block validation rewards and the higher the deterrent penalty for tactors that intend to act maliciously. Without going into deeper technical details about the attack resistance capability of DLT consensus mechanisms, we will consider the aspect of V. Buterin, the co-founder of Ethereum, on the safety of that mechanisms. He notes that "*the mathematical and economic reasoning behind the safety of the consensus mechanisms often relies crucially on the uncoordinated choice model or the assumption that the game consists of many small actors that make decisions independently*" (Buterin, 2017). It is therefore obvious that the higher the number of DLT participants in DLT business ecosystem, the higher the sustainability of the ecosystem stemmed from its security viewpoint.

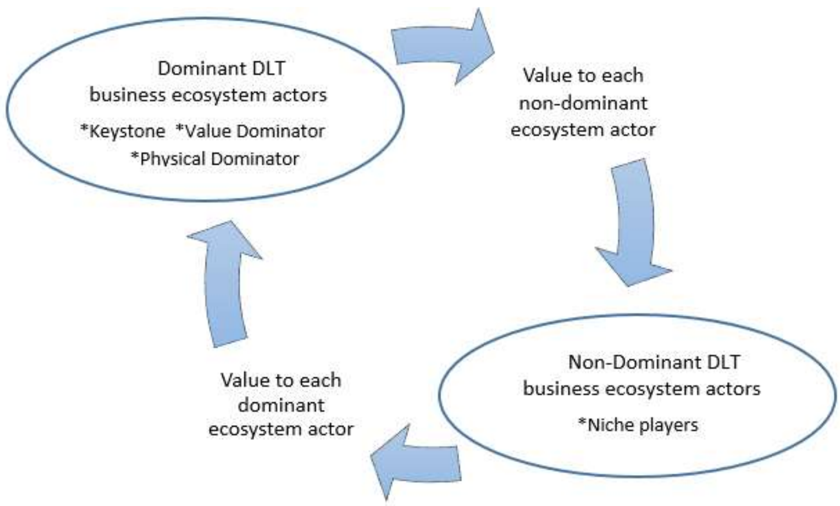


Figure 3: DLT business ecosystem actors and network effect

Apart from ecosystem security, DLT ecosystem expansion is directly associated with the network effect as illustrated in Figure 3. Transparency, traceability, visibility, anonymity, trust between unknown members and cost savings from the removal of middlemen are benefits gained in a DLT ecosystem. The more the actors in the ecosystem, the higher the benefits perceived for everyone in the system and the higher the value created by the system. In DLT ecosystem, actors create value for actors. That case is expected to attract more actors to join the ecosystem, so that more value will be created, and even more actors will be incentivized to join. network effects in the case of DLT ecosystem expansion becomes obvious. When a network effect is present the value of the product or service increases according to the number of others using it (Shapiro and Variahn. 2008). In DLT ecosystem, its expansion is the key for that added value, that in its turn affects ecosystem's sustainability.

DLT encourages interactivity among ecosystem participants and consequently tends to enhance these network effects (OECD,2014). In any ecosystem the rules of governance motivate participation and subsequently affect the emergence of network effect. In DLT business ecosystem, DLT architecture attributes, such as public or private, permissioned or permisionless, as well as the position that actors hold in it, formulate ecosystem governance rules. These rules indicate who and how can participate. The shared value created in the ecosystem, powered by the network effect, is the motivator for the actors to become part of the ecosystem.

1.6 Why we consider DLT ecosystem approach.

A community of organizations and stakeholders compete and collaborate to co-evolve capabilities and deliver goods and services from the innovation process (Moore 1993). Beyond the boundaries of the firm, a network of stakeholders, described as business ecosystem, is created to collectively produce a holistic integrated technological system that creates values for customers (Basole, 2009; Lusch, 2011). Loose interconnection of partners in community, large number of interconnected participants and their interdependence for mutual survival are key attributes of the business ecosystem (Iansiti and Levien, 2004). In its core essence, DLT value lies in DLT network sustainability. Peer-to-peer transactions among network members, large number of participants in network that ensures DLT security and presence of network effect, highlight the business ecosystem approach for DLT. The fact that value created in DLT network is collectively produced by its members and the different roles of loosely interconnected members within the DLT network, enhance the need for ecosystem approach. DLT network members can hold the same roles as the actors that compose the business ecosystem, as described by Moore (1993). Meaning that they can be suppliers, lead producers, customer and market intermediaries, such as agents selling complementary products. DLT can be implemented within an organization with the different business units to serve the role of DLT actors. In our study though, the focus is in DLT ecosystems consisted of a network of organizations and stakeholders.

1.7 What makes a DLT ecosystem sustainable.

Through a combination of digital and business ecosystem success factors we identify what are the factors that apply to DLT ecosystems. Moreover, we define DLT ecosystem health and sustainability. Robustness, productivity and niche creation, are critical success factors of a business ecosystem (Iansiti and Levien 2004), that find direct application to DLT ecosystem. Robustness refers to the capability of business ecosystem to survive from major stresses, such as those that occur by the removal of the dominant DLT ecosystem player or by a strong reduction of the niche player base. In DLT ecosystem a robustness trauma is directly impacts network effect created, due to potential actor base shrink and latency implications, until another dominant player emerges. An antidote to that is the increased engagement that deepens relationships and reduces the chances of partners to jump to a relationship with a competitor.

The degree of business growth created in DLT ecosystem, and value added compose the productivity DLT ecosystem success factor. In DLT business ecosystem, where niche players either contribute with low value creation or they feel that they enjoy disproportional amount of value created by the network, are not incentivized to participate. Niche player participation is associated with ecosystem scale up potential and represents the second stage of the ecosystem lifecycle (Gawer and Cusumano, 2014). The third stage of the ecosystem life cycle, that is also related to DLT ecosystem success, is ecosystem stability and profitability. Profitability is related to ecosystem value distributed to network members and especial to niche players. Stability is affected by ecosystem orchestration and regulation and impacts its members' faithfulness (Jansen, Brinkkemper and Finkelstein, 2013). In DLT ecosystem it can become detrimental when the dominant player imposes too confining regulations. This attitude could enforce superficial versus true collaboration between niche players, especially when considering their relationship with the dominant player. Moreover, it would impact negatively both the opportunities created for the niche players and ecosystem balance.

According to a report by Boston Consulting Group (2019) the more the partners and the more industries they come from the better the ecosystem will fare. This is related to the expertise brought in ecosystem from other industries. Under this aspect scalability and flexibility are considered as DLT business ecosystem success factors up to the degree that they contribute into brining in or linking ecosystem members from a broad variety of industries. Aligned goal and activities bond ecosystem participants to each other toward value creation. These bonds are reinforced though DLT ecosystem member interdependency, that by default condenses their interactions. Therefore, the latter indicates interdependency as an indicator of ecosystem health (Li, 2018).

Even when competition dynamics are developed in the ecosystem, no company competes alone. Moore (1993) emphasizes that it is not the companies that compete but their respective ecosystems. DLT ecosystem is characterized by its member interaction through DLT. Interaction reinforces ecosystem member co-specialization (Li, 2018) and that is a profound prerequisite for DLT ecosystem sustainability. Visibility and transparency in data sharing processes contribute to knowledge sharing and creation. Balance is essential for ecosystem success and sustainability. In DLT ecosystem, niche players participate when their goals are in line with benefits and goals of other ecosystem members. Value creation mechanism should allow DLT ecosystem actors to receive the benefits they expect and consequently keep participating in the value co-creation process. However, evolution of ecosystem dynamics indicates that ecosystem actor relationships change over time. In a healthy ecosystem although this evolution might lead to role changes, it must not affect ecosystem balance. In business ecosystem actors' success is a prerequisite for an organization to achieve its goals. Ecosystem might find another let's call it "goal equilibrium" but still this should keep incentivize ecosystem actors to stay in it. A strong niche player base is decisive factor for DLT ecosystem sustainability. Its expansion that contributes to ecosystem survival depends on DLT scalability and flexibility that facilitates future members to onboard in the ecosystem. Signs such as increased competition among niche players or ecosystem dominant player failure, for instance through financial crisis or when an organization changes its strategical orientation, should be considered as warning messages for ecosystem health. Dominant players usually lie in the center of ecosystem value creation mechanism and their failure or their intention to change strategical orientation may have serious effects to ecosystem balance. These effects may vary from making the value creation mechanism obsolete or even manipulate their relationships with ecosystem actors through the power stemmed by of their position and eventually change the collaboration incentive for other interacting actors. All ecosystem members need to accept a level of ambiguity since controlling ecosystem members and imposing artificial collaboration does not lead to a sustainable perspective.

1.8 DLT ecosystem dynamics.

Ecosystem interdependent organizations feed-off, support and interact with each other exchanging knowledge, resources, products and services (Vidgen andWang, 2006; Tsatsou et al ,.2010). These endogenous ecosystem forces power the co-evolution among ecosystem members, since they force them to evolve reciprocally with each other (Basole, 2009; Teece, 2007; Moore, 1993). Their relationship may be competitive, cooperative or even result in co-opetition (Isckia and Lescop, 2009; Watanabe et al., 2004). In business ecosystems, platform leaders play paramount role in dynamics change when all subsystems are connected in a stable mode through the platform they provide (Li, Y., 2009). Similar to that, in DLT ecosystem DLT architecture is the mechanism that connects ecosystem members' subsystems but neither the technology provider nor the special nature and role of specific ecosystem actors, such as DLT validators, play crucial role in dynamics change. It is the dominant ecosystem player that holds that role. DLT architecture may or may not be provided by the dominant player and that is not the critical point in DLT ecosystem relationship dynamics. It is the power and attitude of the dominant player towards the ecosystem relationship governance. Interdependency of heterogenous partners creates exchange dynamics, that by default transform ecosystem member relationships (Lenkenhoff, et al., 2018). This transformation will constantly alter business ecosystem relationships making competitive, cooperative and co-opetitive relationships being simultaneously present in it. Ecosystems survive due to the adaptability of their interacting entities (Boschma, 2015).

Subsequently preservation of the dynamic attitude in DLT business ecosystem is vital for its sustainability. DLT ecosystem dominant players usually have strong power over the niche players. Attitude of dominant DLT ecosystem players might lead niche players to suffer from coordinated membership and affect deep collaboration. In addition to that an ecosystem is not static especially when its members co-evolve their behavior, attitude, engagement, complementarity and even change roles. In a sustainable DLT ecosystem, all members must seriously consider the strong possibility of the emergence of such dynamics in order to constantly adjust their behavior in a manner that will protect ecosystem sustainability.

1.9 DLT implementation in manufacturing supply chains and business model impact

[2]*As DLT maturity advances, research for DLT implementation in supply chains stems from the advanced information exchange promised. From operational, strategical and sustainability viewpoint, there are not many businesses, that supply chain management affects to such a massive extent the core essence of the business as in manufacturing business. Significance of supply chain collaboration, communication and data exchange along with the importance of relationships established among interconnected parties in a digital connected world, indicates the power of technologies to transform the business model. Let alone in the case of DLT adoption which brings radical changes in supply chain collaboration. Eliminating the dependency and vulnerability of third-party providers, increasing the control over shared information and establishing trust among actors, DLT adoption promises to lower costs, increase visibility, transparency and supply chain efficiency (Bocek, et al. 2017; Nofer, et al. 2017). We therefore set the manufacturing organization in the center of the emerged business ecosystem, recognize the breakthrough innovation that DLT brings at supply chain level and put the notion of trust in the heart of DLT transformation drivers. Under that set up we explore the changes that drive manufacturers to change or innovate their business model.*

Although it is beyond the scope of this study to present a business model definition and despite the ongoing debate on it, we rely on the general assumption that finds the highest consensus among researchers. Meaning that the business model represents the value logic of the company (Fielt, 2013; Osterwalder, et al. 2005; Pateli, and Giaglis, 2004; Wirtz, et al. 2016). Based on literature, when non-trivial changes in at least two business model elements are provoked, then the ‘business model change’ concept is considered (Chesbrough, 2010). Its extension is discussed in literature as business model innovation. Implementation of novel configurations of resources or transactions

---

[2] Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

to serve new markets, test of a completely new generic first appearing business model or even changes and tests in the way that a new idea or technology can be commercialized lay the ground for business model innovation (Bock and Gerard, 2018; Amit and Zott, 2012).[3] *Traits, benefits and specific characteristics that DLT brings both at company and business ecosystem level make it a strong candidate for either business model change or business model innovation conceptualization. Since the same technology commercialized in different ways yields different results, we cannot straightforward conclude that DLT should, by default, trigger any business model change or innovation endeavor. Any new technology implemented could cause changes at strategical, operational, process or market level and not necessarily fuel any changes or innovations at business model level. In the case of manufacturing companies, and under the condition of the networked nature of DLT, we start by exploring the role of DLT at supply chain level with focus on the changes and attributes that its implementation attaches both to company and to the ecosystem. We end up answering the first main research question (mRQ1) of" What are the implicit effects in business model that stem from DLT adoption?"*

Distributed Ledger Technology (DLT) promises decentralization, increased visibility, transparency, anonymity, traceability and higher level of trust among interacting parties (Bocek, T. et al. 2017). Under a supply chain context and in particular when looking into the processes performed in-house, such as in-house logistics, manufacturing, production, quality control, procurement, Production Planning and Control (PPC), data exchange etc., we can easily identify that most, if not all, DLT promises can be met to some extent, by solutions and strategies other than DLT. Literature identifies that disintermediation and trust are key drivers of DLT adoption (Nofer, et al. 2017). Trust is the foundation of every business relationship and the basis of most transactions, whether this is referred to interacting entities internal or external to the company (Rus, 2005).

Intermediaries create trust and must be trusted as well. Organizations are expected to trust their own data kept in their systems and be confident on the way that their internal supply chain operations are performed. In a centralized supply chain almost all interacting entities and data that support the respective processes are expected to be

[3] Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

under organization's direct control. Under that sense, DLT does not seem, at least at first sight, to be needed or to have much to contribute under an in-house supply chain context. To the extent that an organization adopts new ideas and technologies, which affect the generic value chain, the extant business model needs to be at least reviewed (Chesbrough, 2010; Magretta, 2002). DLT adoption at in-house supply chain level, undoubtedly brings massive changes in the value generation mechanism, at least regarding its value creation dimension. Beyond that it is expected to affect all business model dimensions. We will therefore explore DLT adoption causations at in-house supply chain level. Based on the findings we set out to advance our understanding of DLT adoption impact on the business model dimensions, thus answering *the second main research question that is "How DLT adoption causations at in-house supply chain level impact organization's business model?"*

1.10 What ecosystem types and actor roles should we consider when we discuss DLT adoption

[4]*We argue that DLT can be adopted and drive value creation in different ecosystem types. DLT specific characteristics seem to match better to business ecosystem type and based on literature we initially need to explore the analogy between those two structures. We argue that there are similarities between different ecosystem types and to identify how DLT attributes fit to all ecosystem types we recognize the need to review those ecosystem types that their conceptualization is closer to DLT ecosystem approach. Limited research has been done regarding the investigation of the ecosystem type and attributes that fit better to DLT ecosystem approach. Due to the characteristics of DLT there seem to be attributes from many ecosystem types that apply to DLT ecosystem conceptualization. To close that gap, we dive deep into ecosystem definition and literature review, to initially investigate the basic notions of business ecosystems and further develop our understanding on its relevance with DLT. We explore how key business ecosystem definitions, key enablers and evolution from inter-firm relationship*

[4] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, https://doi.org/10.1016/j.techsoc.2022.102143

*to the business ecosystem approach fit to DLT realization. After that we explore similarities and analogies to DLT ecosystem against the business, software, technological, digital, innovation, product and service ecosystem, that demonstrate characteristics which to some degree fit to the DLT ecosystem approach and are therefore considered to be closer to DLT conceptualization compared with other ecosystem types. In that way explore in depth the business ecosystem analogies to DLT ecosystem conceptualization and compare it against other ecosystem types to identify the respective differences and analogies. By answering the first research sub-question of "How do ecosystem types make fit to DLT?" (*subRQ1.1*) we fulfill the need to define what ecosystem type we should consider when we discuss DLT.*

Due to DLT network facet and its specific characteristics we recognize the need to explore what are the factors that define DLT ecosystem sustainability. DLT enabled new ways of value creation sparking the potential to build a foundation for creating unprecedented ecosystems (Iansiti, Lakhani, 2017). Ecosystem actors share a common fate. Over time ecosystem members coevolve their capabilities and roles, tending to align themselves with directions set by one or more central companies (Moore, 1993). Ecosystem crosses many industries and includes actors with different roles. We argue that enforced participation leads rather to superficial than deep collaboration. Shared fate of DLT ecosystem, requires each member, irrespective of its position in it, to have a clear perception of the business value expected to be gained and shared. Given the dynamic nature of the DLT ecosystem we need to explore how its members based on their role contribute to ecosystem sustainability, thus answering *the second research sub-question (subRQ1.2) of "How DLT ecosystem actor based on their role, contribute to ecosystem sustainability?"*. If this promising technology is about to unleash its potential, all interacting actors need to realize how to maintain DLT ecosystem sustainability.

2. Theoretical background

2.1 Business ecosystem perspective

The predecessor of business ecosystem concept has been the ecosystem, derived from the evolutionary theory in biology (Hannan and Freeman, 1997; Adner and Kapoor 2010; Boschma, 2015) Biological ecosystem definitions underline the community aspect of organisms highlighting that it is about systems with complex dependencies that interact and change (*Peltoniemi and Vuori, 2008). In organizational theory the ecosystem approach sees organizations as distinguishable systems that provide complementary contributions. These interdependent bodies have strong ties and loosely coupled internal and external relationships within an ecosystem (Adner and Kapoor, 2010).*

Ecosystems follow the dynamic attitude and evolutionary process of biological ecosystems, that remake themselves reacting to natural disturbances and to the competition among species (World Resources Institute, 2000). Biological ecosystem need to respond and adapt to outside and inside changes. Additionally, the variety of distinct species guarantees ecosystem survival, since it ensures that at least some of them can deal with the new situation. Similar to that in business ecosystems the diversity of ecosystem actors guarantees the ecosystem stability by increasing the possibilities of new space and business opportunities to emerge and therefore adds to the ecosystem faithfulness ecosystem. Analogous to biological ecosystems in business ecosystems participants evolve subsequent to endogenous and exogenous factors. For instance, knowledge exchange and resource leverage are forces internal to the ecosystem that affect the co-evolutionary process, while external factors such as changes to the economic environment, government regulation and technological changes influence the business ecosystem evolution.[5]

---

[5] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

2.1.1 Business ecosystem enablers

According to Moore (2006), the structure and behavior of the network of organizations that form the business ecosystem is empowered by four organizational conditions. Irrespective of organization's strength and ecosystem position in it, all actors need to work together, usually under a key technological platform, to achieve positive sum relationships. Interacting organizations need to collaborate within the ecosystem to thrive in it, since they share its success and failure as whole. On the top of that, collaboration in business ecosystem is strongly related with the creation of complementary capabilities. According to Moore, collaboration boosts the prospects of actors, especially those of the nice players, to leverage complementary resources from other actors and develop specialized complementary capabilities. This is not only a prerequisite for the business ecosystem to thrive, by motivating players to participate in it, but since it fosters innovation, it can be seen as the second condition that enables ecosystem expansion.

By developing complementary capabilities in business ecosystem, actors enhance their differentiation through their specialization reinforcement. Innovation, seen as the result of actor collaboration is the second facilitator and factor of business ecosystem organizational formation. Finding space for business opportunities and developing business within this space are the last two ideas that empower business ecosystem generation and sustainability. Business ecosystem actors join in to benefit from the value creation and mostly of the innovation impulse in ecosystem to enhance their domain of expertise. Innovation and synergies within the ecosystem create space for new business opportunities and especially for nice players that represent the bulk of the ecosystem. When participating in it can be a first-class opportunity to expand their business.[6]

2.1.2 From inter-firm relations to business ecosystem

Inter-firm relations stemmed from the service and product development disintegration are considered to be the predecessor of business ecosystems (Iansiti and

[6] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

Levien, 2004). These relations pushed towards the creation and evolution of networks and alliances. Organizations realized that risk sharing, access to collaborative knowledge and exogenous change responsiveness has been proven to act to their benefit through inter-firm network formation (Iansiti and Levien, 2004; Eisenhardt and Schoonhoven, 1996). Although literature addresses the impact of inter-firm networks, in particular for the technology industry, findings have proven that this impact applies to a wide spectrum of industries. Studies have shown that firm performance, speed of innovation and organization are positively impacted by inter-firm network formation (Ahuja, 2000; Gulati et al., 2000). Business ecosystem, although often described through the lens of the technology sector, is approached as the community structured by the interactions formed by complex inter-firm networks (Green and Sadedin, 2005).

*Systems theory and complexity light up inter-firm network complexity. It is seen as the actor differentiation that given the degree of independency enables ecosystem self-organization through the high degree of actor interaction and interconnection. In his fundamental study Moore (1996), unfolds the evolution from core business to the extended enterprise and expands it further to the business ecosystem approach. He acknowledges that business ecosystem is an extension of the loosely coupled self-organizing network of firms to an extended system of mutual supportive organizations (Moore,1996)**.** Although this has been a latter business ecosystem definition by Moore it emphasizes the cluster concept along with the decentralized decision making and self-organization (Peltoniemi and Vuori, 2008).*[7]

2.1.3 Ecosystem definitions and literature review

Moore was the first to introduce the concept of business ecosystem as a biological metaphor of organizational behavior and community structure into social systems. In those systems, tactors' roles bring them together into networks that success and failure is shared as whole. According to that approach business ecosystem is an economic community consisted of organizations, that although independent, interact either cooperatively or competitively in production, customer service and innovation (Moore,1993). This definition underlines the interactions within a business ecosystem,

[7] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

since it highlights the horizontal relationships among network participants. The diversity of an organization operating within a business ecosystem, in relation to the relationships developed has been supported to be a decisive factor for business ecosystem self-organization and adaptability (Peltoniemi et al., 2005). The outside in approach in business ecosystem structure and adaptability suggests that organizations develop their internal processes and interfirm relationships, thus formulate and reciprocally reshape the business ecosystem structure and its shared fate based on the diversity of their environment (Peltoniemi et al., 2005). The set of positive sum relationships between interdependent ecosystem actors has also been recognized by other scholars (Basole, 2009; Dougherty and Dunne, 2011). Moore (1996) focuses on firm networks and sees their economic activities as undivided per specific industry, supporting that the term business ecosystem should be replaced the term 'industry'.

Some scholars are going beyond this interfirm symbiosis concept to introduce human network integration in business ecosystem concept, such as interconnections between executives (Ibarra and Hansen, 2011; Vargo and Lusch, 2004). Other studies present business ecosystem as a concept similar to value network, where beyond firm boundaries the nested commercial systems comprise a complete, nested set of products and services that define a specific market demand. This approach highlights the innovation prospect in value networks counting them as a model description of both context and content, where each company engaged in it contributes a specific component to deliver product and service to a specific demand (Christensen and Rosenbloom, 1995). The collaborative effort to drive value creation that no single ecosystem member could create itself is mentioned in almost all business ecosystem concepts (Adner, 2006; Iansiti, and Levien, 2004). In an effort to understand business networks, the biological ecosystem analogy has been addressed by various studies. These studies recognize the large number of network members and their loosely coupled interconnection and interdependency that determine their mutual effectiveness and the ecosystem shared fate and health (Iansiti and Levien, 2004).

The focus on innovation and business ecosystem approach in literature has also been revealed by studies that go a step beyond defining the scope of a business ecosystem. Thos studies address the need of multinational companies to manage innovation through their strategic keystone role in it as platform leaders (Hauptman, 2003). Other studies manifest organizations' need to to manage the entire ecosystem and the organization as an entity on its own (Power and Jerjian, 2001). Although these *studies derive their assumptions from the integrated electronic business point of view, they introduce a resource-based view for ecosystem prosperity, stress the ecosystem standpoint and consider the advantages of cooperation. Despite their strong emphasis on the technological aspect of the networked information economy other studies contribute to business ecosystem concept by featuring the importance of information exchange boosted by the connectivity between ecosystem members as the main driver of ecosystem value creation. They indicate that it is the business ecosystem concept that alters the interfirm relationships and not the other way round (Gossain and Kandiah, 1998). Other studies see that it is the interconnectedness that causes the changes in the landscape occupied by an organization within the ecosystem. Since each networked actor landscape is being coupled to many other changes in one ecosystem member, it has an impact on the landscape of other actors such as competitors, collaborators and complementors that results into reshaping the business ecosystem (Lewin, 1999).*[8]

2.2 What DLT ecosystem is not.

To identify what type of ecosystem is the most appropriate to consider for DLT we will critically examine the ecosystem types that are closer to the DLT conceptualization. DLT is an innovative digital technology that designates the transactions between ecosystem members. We will therefore the software, digital, technological, innovation, product and service ecosystem types that are demonstrate characteristics that to some degree fit to the DLT ecosystem approach. Our purpose is to identify how do these ecosystem types match for DLT as illustrated in Table2.

[8] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

Ecosystem Types	Similarities to DLT Business ecosystem	Where DLT business ecosystem doesn't fit to other ecosystem types
Software ecosystem	-A set of software solutions and common software platforms that support and empower transactions. - Emphasize in member interconnectedness.	-DLT ecosystem is not being drawn up by software service providers and software vendors. - DLT ecosystem actor relationships are affected but not defined by software platforms.
Technological ecosystem	-Ecosystem actors elaborate the technology challenges in the development, availability, performance, connectivity and efficiency of a specific technology. -Information exchange plays a central role	-DLT ecosystem contributes in the creation and the delivery of technology products and services but this is not its scope. - The scope pf DLT ecosystem is not to expand the system of use. DLT is the component upon which organizations build platforms
Digital Business ecosystem	-Ecosystem actor interaction and the distributive nature of the environment. -The role of digital infrastructure as self-organizing mechanism. -Prosperity of digital technology plays a significant role in the fate of the ecosystem.	-DBE focuses in the software environment created and not in the business environment formed through ecosystem actor relationships and interaction. - DBE challenges are mainly related to its technological traits, such as IT, data exchange rules, digital interfaces and not to actor dynamic relationships, capabilities co-evolution, trust in ecosystem and value of data management. -Role definition and ecosystem positioning in DLT business ecosystem is not solely conceived around the information flow notion as in DBE.

Table 2: Comparison between DLT ecosystem and similar ecosystem concepts (Papanikolaou, Angelis and Moustakis; 2023. Which type of ecosystem for Distributed Ledger Technology?)

Ecosystem Types	Similarities to DLT Business ecosystem	Where DLT business ecosystem doesn't fit to other ecosystem types
Service ecosystem	- Value co-creation through service exchange. - Emphasize in the collaborative process and recognize the foremost importance of the information technology. -Actors create value for actors.	- Service ecosystem does not address competitive relationships that raise barriers to value co-creation are absent. - In DLT business ecosystem the product can also be the basis of exchange - In DLT business ecosystem actors are not necessarily resource integrators as in service ecosystems. - In DLT business ecosystem actors contribute in the same value chain participating in value adding activities
Product ecosystem	-Value co-creation includes the synergistic benefit of users, complementors and producer networks. - The high importance of market based assets and relationship with entities that exist outside the firm.	- Product ecosystem's scope is to add value to the product itself, enhance the attractiveness of the associated focal product and increase customer loyalty but does not address the value shared to other ecosystem stakeholders. - In the product ecosystem network effects focuses on the number of products and on not the ecosystem actors that interact for value creation. - In DLT business ecosystem the central notion is not the product and its success
Innovation ecosystem	-Co-specialization, bargaining power and relationships impact the value captured by the focal firm. -Ecosystem actors co-evolve capabilities -The dominant ecosystem actors sets the ecosystem direction .	- DLT might include but is not an ecosystem of interdependent innovations. - Innovation ecosystem actors are defined based on their upstream and downstream role around the focal innovation and based on the relationships to the focal actor. - The number of innovation actors is not critical to the ecosystem sustainability for the innovation ecosystem as is to the DLT business ecosystem. - Customer demand side is absent in innovation ecosystem. - Participant diversity is not essential in DLT business ecosystem as is in the innovation ecosystem.

Table 2 (continued): Comparison between DLT ecosystem and similar ecosystem concepts (Papanikolaou, Angelis and Moustakis; 2023. Which type of ecosystem for Distributed Ledger Technology?)

2.2.1 DLT ecosystem is not a software ecosystem.

Scholars have used similar constructs to describe the ecosystem such as the software ecosystem (Jansen et al., 2013). Ecosystems formulated due to its member interconnectedness through DLT and blockchains should not be confused with software ecosystems (SECO). dApps that incorporate DLT are critical for the expansion of the ecosystem powered by blockchain, since they facilitate DLT adoption. However, the ecosystem created by organizations participating in the blockchain is not a software ecosystem. A SECO is consisted of a set of software solutions that support and empower the transactions of organizations participating in a social or business ecosystem (Bosch, 2009). In a SECO the network is being drawn up by software service providers and software vendors, that depend on other software vendors for software components and infrastructure.

The SECO concept is closely related to the technology-based ecosystem, as it reflects the need of software vendors to establish networks to meet the quickly changing technology challenges in the development, availability, performance, connectivity and efficiency of software elements and infrastructure. The software ecosystem approach is the expanded view of the software services market between the actors that function as unit of the due to the need of software interoperability and software vendor alliances. Common technological platforms, operating systems, libraries and component stores usually ground the SECO actor relationships through the Information, resource and artifact exchange (Jansen et al, 2009). DLT definitely defines the dominant design of the platform in the ecosystem and some of the actors may hold the role of software vendors but the ecosystem created through the DLT adoption is not a network of software vendors. However, a SECO might be deployed in a DLT business ecosystem, since platform interoperability, the variety of DLT designs and the creation of programmatic connections and protocols between DLT networks creates space for software vendor collaboration.[9]

2.2.2 DLT ecosystem is not a technological ecosystem.

[9] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

Like SECO, the technology-based ecosystem and more specific the information technology ecosystem can also be confused with the ecosystem created when actors interact through DLT. We could assume that each SECO is an ecosystem based on specific technology. The technology ecosystem is the expanded view of network of organizations that drives the creation and the delivery of technology products and services. In these networks technology vendors are surrounded by non-technology producing organizations such as integrators service suppliers, etc. A technology-based ecosystem is not the sum of its parts such as independent technology providers, customers, resellers, outsources and technology standard regulators.

Core technological components, such as platforms, surrounded by complementors, such as applications connected or built upon the core solution made by independent companies, offer solutions comprising a larger system of use than the original technology component provider (Iansiti and Richards, 2006). The scope of the technology-based ecosystem is to expand the system of use, through its actor co-evolution and interconnectedness, to solve technical problems within an industry. In a technology-based ecosystem it is the complementary technological innovations that are built upon the core technology that drive the ecosystem value creation **(***Gawer and Cusumano, 2014). The role of DLT as the component upon which organizations build platforms and definitely plays a fundamental role in the business ecosystem should not be confused with the role of the platform as the interacting functional element in a technology-based ecosystem. In an ecosystem formulated due to DLT adoption there may be platforms at different levels of the system hierarchy (Makinen and Dedehayir, 2012).*[10]

2.2.3 DLT ecosystem is not a digital business ecosystem.

The digital business ecosystem (DBE) concept has been introduced in 2000 in the field of business research and has been further elaborated in the EU Framework programs FP6 and FP7. It was based on enhancing the potential of the SMEs to compete with larger software houses (Korpela et al., 2013). Ecosystem actor interaction and the distributive nature of the environment that it creates appear to be

[10] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

common aspects with the ecosystem generated through the DLT adoption. Although later studies expanded the definition of the DBE, the basic difference between these two ecosystems lies in that the DBE focuses in the software environment created and not in the business environment formulated through ecosystem actor relationships. The synthesis of the literature in DBE stresses the weight of digital infrastructure not only as an accelerator of environmental turbulence that drives new forms of value creation but also as the self-organizing mechanism (Power and Jerjian, 2001).

Other definitions of DBE highlight the self-organizing behavior of organizations boosted by high level internet-based technology maturity that fundamentally supports the business services. The digital environment enables independent species in it, such as components, applications, services, business models, conceptual frameworks to interact, co-evolve and share a common fate. DBE fate stems from the interest in the prosperity of the digital technology (Zachman, 1999). DBE ecosystem concept is closer to the technology-based ecosystem rather to the business ecosystem powered by blockchain. DBE challenges are related to technological traits such as incompatibility of information technology, data exchange rules and digital interfaces (Lenkenhoff et al., 2018; Chen, Vallespir and Daclin, 2008). Although DBE actor related challenges, such as partner competences, are linked with the origin of the ecosystem definition, role definitions are conceived around the ecosystem information flow notion (Karakas, 2009; Adner and Kapoor, 2010). In a business ecosystem where DLT is the connecting bond between actors, the prosperity, self-organization and evolution resulting from the member exchange dynamics is being assisted by but not happening due to DLT or any blockchain dApp development. [11]

2.2.4 DLT ecosystem is not a service ecosystem.

Service ecosystem is defined as a system of loosely coupled resource integrators, interacting through technology and service exchange (Vargo and Lusch, 2016). Service ecosystem concept emerged as an evolution of the service dominant logic. It may happen that fundamental constructs of the service ecosystem such as service exchange, value co-creation and in some cases resource integration are identical to a specific

[11] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

structure of a business ecosystem formulated based on DLT. This is obvious in a DLT business ecosystem, where service is the fundamental basis of exchange and competitive relationships that raise barriers to value co-creation are absent. Although both service and DLT business ecosystems emphasize in the collaborative process and recognize the foremost importance of the information technology, we can spot substantial differences between them. In DLT business ecosystem, relationships may vary from competitive, to cooperative and co-opetitive and the basis of exchange can be both product and service. On the top of that in DLT business ecosystem all actors are not necessarily resource integrators, while on the contrary this is a core trait in a service ecosystem (Akaka et al., 2013). The most significant difference lies in the fact that in a service ecosystem actors make value propositions to each other and not deliver or add value (Lusch, 2011). In DLT business ecosystem although actors may create value for actors, actors contribute in the same value chain participating in value adding activities. In service ecosystems institutions are seen as the foundational social aspects of value creation. Although institutional arrangements can be reflected through smart contracts as the DLT business ecosystem equivalent (Kaartemo et al., 2017), the role of institutions as intermediaries in service ecosystems is controversial with the core decentralization logic of the DLT business ecosystem. [12]

2.2.5 DLT ecosystem is not a product ecosystem.

Product ecosystem has been referred in literature as a whole product pointing out the perspective to provide the customer with a complete solution (Lambkin and George, 1989). The scope of product ecosystem has been defined to provide the customer a compelling reason to buy. This approach emphasizes into the complementarity of the elements external to the focal product that drive its purchase. For instance, software, training, support, additional hardware and other compatible to the focal product services and products that contribute in focal product completeness are considered as part of the product ecosystem. Other researchers have named the industry and the product infrastructure to compose the product ecosystem (Lambkin and George, 1989; McIntyre, 1988). A synthesis of the literature suggests that the synergistic benefit of

[12] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

users, complementors and producer networks is seen as the product ecosystem composition that intends to add value to the product itself, enhance the attractiveness of the associated focal product and customer loyalty (Frels, Tasadduq and Rajendra, 2003). Complement's network is based on the principle that the more the complement products the more useful the focal products. User network approach is based on the early adopter's influence on the non-adopters. Producer network is a resource-oriented approach and involves the original and competitive product manufacturer. These actors target into increasing the size of the potential market either by cooperation or by co-opetition that offers synergistic effects such as resource price reduction (Kotabe, Arvind and Preet, 1996).

Product ecosystem's core essence lies in the market-based assets, meaning entities that exist outside the firm. This can be recognized as highly similar to the DLT business ecosystem traits. The interdependencies and market relationships of competitors, complementors, producers, suppliers, distributors and users enhance ecosystem value creation. However, in a DLT business ecosystem the central notion is not the product as a whole, meaning as set of entities that will make the focal product more lucrative for the customer. This is only one aspect of a customer-oriented business ecosystem where product acceptance and customer experience are inextricably linked with the success. The product ecosystem may well be a subset of the DLT business ecosystem. The latter includes actors such as service providers, regulators, trade associations and other stakeholders that contribute to the product value. However, the added value that they enjoy is not necessarily associated with the success of a specific product. For instance, in a DLT business ecosystem a distributor contributes in the product success through the transparency and traceability of his services. At the same time the added value that he enjoys is not related with the success of a specific product. The same applies for instance, for a hospital that participates in a health DLT business ecosystem. The insurance company enjoys the synergistic benefits of the DLT business ecosystem, that will be probably reflected on its product characteristics and may even have an impact on its success but the hospital will enjoy the benefits of the same ecosystem irrespective of the success of that insurance product. [13]

[13] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

2.2.6 DLT ecosystem is not an innovation ecosystem.

Innovation ecosystem concept was introduced in 2006 as an ecosystem of interdependent innovations. The basic idea behind that is that a successful innovation depends on the focal firm changes in its environment (Adner, 2006). Apart from the core innovator, innovation ecosystem actors are also its upstream and downstream suppliers and complementors. In that ecosystem its members flourish when all ecosystem partners, not only the core innovator, make it to resolve their innovation challenges (Tushman and Anderson, 1986; Christensen 1997). Dynamics of value creation in an innovation ecosystem are determined by the magnitude and the location of innovation challenges. Magnitude represents the degree of changes required to the current problem-solving approach. Location, components, recognized as upstream, or complementors, recognized as downstream, to the focal innovator partners, are seen as the structure of technological interdependence that impact its ability to create value (Adner and Kapoor, 2010).

Both in a DLT business and in an innovation ecosystem co-specialization, bargaining power and relationships impact the value captured by the focal firm. In addition to that in both ecosystem types upstream and downstream to focal partners will co-evolve capabilities and adopt their innovation in alignment to the direction set by the central or else dominant focal company. However, in DLT business ecosystem the network effect created through high level of participation will be negatively impacted by superficial collaboration, while in the innovation ecosystem the number of external upstream or downstream innovation actors is not critical to the ecosystem sustainability. In the innovation ecosystem the scope is all ecosystem actors to co-evolve their diverse capabilities and not necessarily more actors to join the ecosystem. The more diverse the nature of participants and resources required to formulate the innovation ecosystem the higher the number of the actors in it but the large number of ecosystem members is not a prerequisite for the innovation ecosystem sustainability. In the innovation ecosystem the value chain position of an exchange partner relative to the focal firm does not affect differently its ability to capture value. In the DLT business ecosystem the customer demand side, that is absent in innovation ecosystem (Wright, 2012), weights differently the position of the exchange partner relative to the focal firm's ability to capture the value created. The customer demand side in the DLT business ecosystem highlights the need for partner collaboration to create and deliver *solutions that meet the full package of value to the customer (Moore, 1993). Absence of customer demand side in innovation ecosystems stems from its focus on how ecosystem development is achieved based on the innovation and how to make up and scale the transformative impact.* [14]

2.3 Why the business ecosystem type fits to DLT networks

The interactions between complex inter-firm networks structure a community that in literature is approached as business ecosystem. Moore (1996), views business ecosystem as the evolution from the extended enterprise concept. When organizations adopt and interact through DLT, the inter-firm network interconnectedness shapes the DLT business ecosystem. In that ecosystem customers, lead producers, competitors, standard bodies, various associations, other stakeholders and interested parties are mutually supported by DLT through their interaction. These actors that are by default the business ecosystem actors emphasize the decentralized nature of the decision-making (Moore, 1998). These actors seek the value generated from the positive sum of relationships created through DLT powered collaborative interactions. This is the business ecosystem scope as described by Moore but in our case it the DLT architecture that defines its specific nature. DLT introduces a new way that cryptographically validated data that users can't corrupt, are moved and stored in blocks. DLT mechanism includes by default the concept of network, since it proposes a new way that data are moved, accessed and stored in a decentralized way. In DLT inter-firm network, in accordance with the decentralized decision-making basis of the business ecosystem, decentralization is promised through transactions without the need of intermediaries. DLT interactions are performed by loosely coupled independent organizations seeking to leverage the DLT benefits in order improve their mutual effectiveness[10].

Benefits that lie in data sharing, data access, promotion of knowledge generation through DLT mechanism, innovation and new business space creation. Analogous to all ecosystem approaches, where mutual supportive actors collaborate to create value that no single member could create itself (Adner, 2006; Iansiti and Levien, 2004), DLT interconnected actors create value for actors. In business ecosystem interdependent

[14] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

organizations feed-off, support and interact with one another in exchanging knowledge, resources, products and services (Vidgen and Wang, 2006; Tsatsou et al., 2010). Similar to that DLT transactions reinforce knowledge creation and enhance member capabilities co-evolution. The way that data are accessed, the transparency and visibility demonstrated offer the DLT network members the perspective to exploit data and create new data driven knowledge. This knowledge, along with trust that DLT member collaboration generates, reflects one aspect of the collectively produced value in business ecosystems. Another vital characteristic of both DLT networks, ecosystems and business ecosystems is the number of their members. The large number and the variety of participants is fundamental in the ecosystem and business ecosystem approach. The same applies in DLT networks, since high number of members does not only contribute in network security but also promotes network sustainability, through the respective network effects developed.

Collaboration, capabilities co-evolution, space for business opportunities and business development within that space are four business ecosystem enablers as described in literature (Korpela et al., 2013). In DLT networks potential participants are incentivized by knowledge creation and the efficiencies that DLT brings. The power of data driven decisions, the knowledge generated and the capabilities co-evolution that the participation in a DLT driven network brings are basic elements that allow innovation to prosper. In addition to innovation, synergies created with collaborations allow organizations participating in the network to explore and identify space for new business opportunities. We could therefore include the space and the business development as DLT inter-firm network enablers, the same as in business ecosystems.

The roles of the keystone and the physical dominator are inherent to the business ecosystem definition (Moore, 1993; Hauptman, 2003). Keystone actors are usually referred as ecosystem leaders and aim for leadership by regulating the business ecosystem. The physical dominator imposes his dominance with strategies and intends to extract and keep the maximum value generated in the ecosystem for himself. There is a profound analogy between the business ecosystem roles and the roles in an DLT network as illustrated in Table 3, DLT networks emphasize the importance of the DLT architecture as a factor that defines significantly the nature of the network and the relationships that will be developed in it.

Key characteristics of Business Ecosystem	DLT Ecosystem analogy
Actor interconnectedness	Interconnection through DLT transactions
Decentralized nature of the decision-making	Decentralized nature of DLT driven decisions without the need of intermediaries
Value generated from the positive sum of relationships	True collaboration to incentivize niche participation and enhance positive network effects
Networked perception	The decentralized nature of data exchange, access and storage that is proposed by DLT by default includes the networked perception
Interdependent organizations feed-off, support and interact with one another in exchanging knowledge, resources, products and services	Actors create value for actors through transparency, visibility, information exchange and data access
Large number of actors	Network effect is critical for DLT ecosystem security and viability
Roles of keystone, physical dominator, value dominator and niche players	Roles of ecosystem dominant and non-dominant/niche players
Network of organizations that share a key technological platform	DLT is the technological connectors between ecosystem actors

Table 3: DLT ecosystem analogy to business ecosystem perception (Papanikolaou, Angelis and Moustakis; 2023. Which type of ecosystem for Distributed Ledger Technology?)

A network member, usually the one with the most dominant position in the network or the one with the highest power over it partners, holds the role of the DLT network regulator. He may not be the platform provider but has the power to impose the DLT architecture characteristics, that will define the nature of the DLT network to be formatted. The degree of data openness and the private or public nature of the DLT are decisions of paramount importance that shape the DLT network.

We summarize that inter-firm networks demonstrate the same fundamental characteristics to the business ecosystem and that analogies between these two structures lie in the core of their existence. Inherent DLT characteristics that form the DLT inter-firm network demonstrate profound analogies to the business ecosystem concept. Similarities and analogies between these two structures lie not in only in the structure, the actors, the roles they hold, their relations and the health factors but also in the essence of the scope of their formation.[15]

2.4 Actors and roles in DLT Ecosystem

The actors within a business ecosystem can be classified in three categories that are, the dominator, keystone and niche players (Iansiti and Levien, 2004; Shapiro and Variahn, 2008). The dominator is able to control the maximum nodes within its network and is in position to extract the value of the network without redistributing it. For an ecosystem actor that holds either the role of the physical dominator, who imposes his dominance with integration strategies, or the role of the value dominator, who is interested only in extracting the maximum value and overlooks dominancy, the common area is the intention it to keep the value for himself. Keystone actor participates in value creation and share, plays a predominant role in the ecosystem and aims for leadership by regulating it. Keystone players are usually referred as platform leaders or ecosystem leaders (Moore, 1996; Cusumano and Gawer, 2002). The key to their success is to provide the appropriate tools, technologies, processes and services for ecosystem value creation. Their role is to ensure ecosystem sustainability through a well functioned network and ecosystem actor retention. Niche players are those that have a small role, or a small part of their activity is engaged in the value creation process of the ecosystem. They are differentiated actors, utilize the tools provided by the keystone players and contribute to ecosystem's evolution and dynamics.

In DLT business ecosystem, the keystone player may not be the platform provider but hold the role of the ecosystem regulator. Depending on the DLT architecture, the platform provider may even be an actor other than those interested in the benefits of value co-created in the ecosystem. For instance, a dApp provider or a DLT platform

[15] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

provider may well be interested in the value created in the network only to the point that the platform remains viable and active for the ecosystem. In our study we considered data management and data openness, as the crucial factors for DLT ecosystem regulation. We argue that in DLT ecosystem there is no player that acts as a dominator, as described under the business ecosystem concept, in terms of maintaining the value created in the network for herself. Any such strategy would create a negative network effect in the DLT ecosystem and on the top of that would foster superficial versus deep collaboration among network actor. The latter that would obviously negatively impact ecosystem's sustainability.

We classify DLT ecosystem actors in two categories, the ecosystem dominant and non-dominant players. Dominant players in terms of network relationship, power dynamics, brand or financial strength are positioned at the center of the ecosystem and initially set the rules of collaboration. We underline the rule setting and governance traits of those actors the DLT ecosystem because as the ecosystem expands it may happen that other actors, either individually or along with their own ecosystem, to become part of the network. In that case and based on the dynamic feature of the relationships in the DLT ecosystem, the number of dominant players can rise or put simply, role changes might occur. Dominant actors in DLT ecosystem embody attributes of both the dominant and keystone players, as described in business ecosystem literature. The other group of DLT ecosystem actors are the niche players. These actors exactly as conceptualized in business model literature symbolize the non-dominant players.

2.5 DLT ecosystem sustainability

In this section we identify what are the factors that apply to DLT ecosystems and define its health and sustainability. Robustness, productivity and niche creation, being the critical business ecosystem success factors (Iansiti and Levien, 2004), find direct application to DLT ecosystem. Robustness refers to the capability of the business ecosystem to survive from major stresses, such as those that caused by the removal of the dominant DLT ecosystem player or by a severe reduction of the niche players. In DLT ecosystem the robustness trauma is directly related both to the impact of the network effects, due to participant base shrink and to latency implications, due to the replacement of the dominant player. An antidote to those shocks is the increased actor engagement that deepens relationships and reduces the chances that actors will leave the ecosystem.

The degree of value and business growth created in DLT ecosystem reflect the productivity success factor. When niche players either contribute with low value creation or feel that they enjoy disproportional amount of the value created by the network, are not incentivized to participate. Niche player participation is associated with the scale up potential of the ecosystem and represents the second stage of the ecosystem lifecycle (Peltoniemi and Vuori, 2008; Kaiser et al, 2021). The third stage of the ecosystem life cycle, that is also related to the DLT ecosystem success, is the ecosystem stability and profitability. Profitability is related to the ecosystem value distributed to network members and especial to niche players. Stability is affected by the orchestration and regulation of the ecosystem and impacts the loyalty of its members (Jansen et al., 2009).

In DLT ecosystem it can become detrimental when the dominant player imposes too confining regulations. This would enforce superficial versus deep collaboration between niche players, in regard to their relationship with the dominant player. That would have negative impact both on the opportunities created for the niche players and on the ecosystem balance. Scalability and flexibility are considered as DLT business ecosystem success factors, to the extent they contribute into brining in or linking ecosystem members from a broad variety of industries. Aligned goal and activities bond ecosystem participants to each other toward value creation (Senyo, Liu and Effah, 2019). These bonds are reinforced though the DLT ecosystem member interdependency, that by default condenses their interaction. Hence, we argue that interdependency is an indicator of ecosystem health (Li, 2018). According to a report by Boston Consulting Group (2019), the more the partners and the industries they come from the better the ecosystem will fare. This conclusion is related to the expertise brought in the ecosystem from other industries.

Moore (1993) notes that it is not the companies that compete but their respective ecosystems. Interaction reinforces ecosystem member co-specialization (Li, 2018) and that is a profound condition for DLT ecosystem sustainability. We argue that balance is essential for ecosystem success and sustainability. Niche players participate when their goals are in line with the benefits and the goals of other DLT ecosystem members. The value creation mechanism should allow DLT ecosystem actors to capture the benefits they expect and keep participating in the value co-creation process. However, the evolution of ecosystem dynamics indicates that ecosystem actor relationships change over time. Although this evolution might lead to role changes, in a healthy ecosystem it should not affect the ecosystem balance. In a business ecosystem actors' success is a prerequisite for an organization to achieve its goals. Irrespective of the "goal equilibrium" achieved in the ecosystem it must incentivize all actors to stay in it.

A strong niche player base is a decisive factor for DLT ecosystem sustainability. Its expansion contributes into the ecosystem survival and depends on the DLT scalability and flexibility to attract its future members. Signs such as increased competition among niche players or dominant player failure, for instance in the case of a financial crisis or strategic reorientation, should be considered as warning messages for ecosystem health. Dominant players usually lie in the center of ecosystem value creation mechanism and their potential intention to leave the ecosystem will have a serious effect to the ecosystem effects. These may vary from making the value creation mechanism obsolete or even manipulate their relationships with ecosystem actors through the power of their position and eventually undermine value created through deep collaboration.

2.6 DLT ecosystem dynamics

Ecosystem interdependent organizations feed-off, support and interact with each other by exchanging knowledge, resources, products and services (Vidgen and Wang, 2006; Tsatsou, et al., 2010). These endogenous ecosystem forces power ecosystem member co-evolution (Moore, 1993; Basole, 2009; Teece, 2007). Their relationship may be competitive, cooperative or even result in co-opetition (Basole, 2009; Isckia and Lescop, 2009; Watanabe et al., 2004). In business ecosystems, platform leaders play a paramount role in dynamics change when all subsystems are connected in a stable mode through the platform they provide (Li, 2009). Similar to that, in DLT ecosystems DLT architecture is the mechanism that connects actors and subsystems but neither the technology provider nor the nature of some actors, such as the validators, play crucial role in dynamics change. It is the dominant ecosystem player that holds this role. DLT architecture may or may not be provided by the dominant player and that is not the critical point in DLT ecosystem relationship dynamics. It is the power and attitude of the dominant player towards the ecosystem governance. Interdependency of heterogenous partners creates exchange dynamics, that by default transform actor relationships (Lenkenhoff, et al., 2018).

This transformation will constantly alter business ecosystem relationships making competitive, cooperative and co-opetitive relationships being simultaneously present in it. Ecosystems survive because of the adaptability of entities and their interaction (Boschma, 2015). Preservation of the dynamic attitude in DLT business ecosystem is vital for its sustainability. Dominant DLT ecosystem players usually have strong power over the niche players. The attitude of the dominant actors might lead niche players to suffer from coordinated membership and affect deep collaboration. In addition to that an ecosystem is not static, especially when its members co-evolve their behavior, attitude, engagement, complementarity and even change roles. In a sustainable DLT ecosystem, all members must seriously consider the strong possibility of the emergence of any such dynamics to constantly adjust their behavior in a manner that will protect ecosystem sustainability.

.

2.7 DLT ecosystem endogenous and exogenous forces of evolution

Ecosystems evolve subsequent to endogenous and exogenous forces (Makinen and Dedehayir, 2012). Co-evolutionary process is a force internal to the DLT ecosystem. Actor co-evolution is based on the knowledge and resource transfer, that occurs when DLT actors interact with each other. Ecosystem members leverage DLT powered data transfer and have the opportunity to create new knowledge, advance their capabilities and achieve new level of trust. Evolution of one ecosystem member affects the evolution of other actors and consequently feeds the value generation mechanism in the DLT ecosystem. Actor co-evolution is associated with both competitive and cooperative relationships (Agiza, et al., 1997). Meaning that both negative and positive interactions trigger the development of capabilities and knowledge of interacting parties. In that way ecosystem members either aim to improve their strategic position towards their individual goal, in the case of competition, or develop capabilities in order to achieve their common goal in a cooperative relationship.

DLT architecture is more that an endogenous factor, which defines DLT ecosystem evolution. It is rather an inherent characteristic of the ecosystem, that lies in the heart of its evolution as illustrated in Figure 4. The degree of ecosystem openness, along with the objectives that DLT architectures try to meet, define the evolution of the ecosystem.

It is not only the restrictions and benefits that are defined by DLT architecture but also the interdependence and the need for connection between different ecosystems. DLT architecture design reflects the ecosystem value creation scope and the expected actor benefits. Apart from that we argue that interacting actors may belong to different ecosystems and the modularity of each ecosystem architecture impacts evolution acceleration. For instance, the need for off-chain data storage and its collaboration with DLT, as well the interaction between different DLT ecosystems impacts ecosystem evolution, since DLT architecture is the mechanism that connects the ecosystem subsystems. Modular systems theory notes that high rates of evolution is related with the degree of modularization because subsystems evolve independently (Makinen and Dedehayir, 2012).

In business ecosystems, platform architecture is strongly related with platform governance. However, in a DLT business ecosystem DLT governance is not an endogenous factor of evolution. This is happening due to the distributed nature of DLT and the respective ecosystem's characteristic of the absence of central trusted authorities and middlemen. The degree that one ecosystem member influences the design rules and DLT architecture, is defined by its role in the ecosystem and the power attitude that the keystone, or else the dominant DLT ecosystem, player demonstrates. We argue that the co-evolutionary processes will still be in place irrespective what attitude do the dominant players demonstrate. After all, this will affect the degree of the evolution not the evolution reality.

Role change in is an endogenous factor of DLT ecosystem development. Ecosystems are not static, they evolve and with them their members evolve their capabilities, relationships and strategies. Role changes do not only reshape DLT ecosystem dynamics but can fundamentally redefine ecosystem objectives. This is a severe change that affects DLT ecosystem evolution. Although the value generation mechanism might not change, actor relationships and consequently ecosystem dynamics, nature of collaboration, participation incentives and value sharing analogies will be affected.

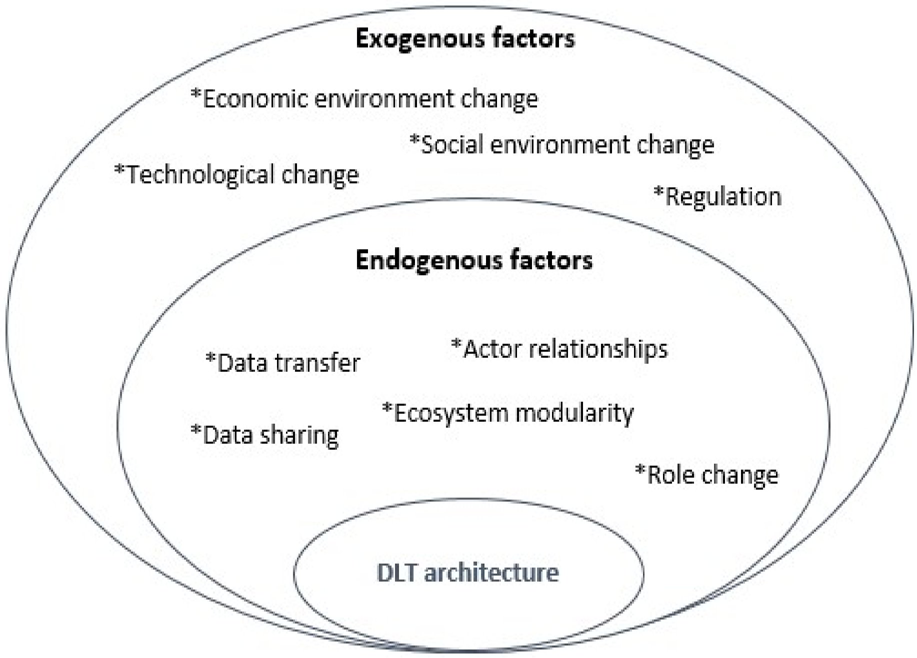


Figure 4: DLT business ecosystem endogenous and exogenous factors of evolution

External DLT ecosystem evolution factors are sourced by the ecosystem environment. Changes in economic and social environment affect ecosystem composition and orientation. Composition changes when actors join and leave the ecosystem. That might happen either because either actors do not capture the expected benefits or because their own strategic orientation alters their business priorities or objectives and the current ecosystem does no longer meet them. The latter can also be triggered by market changes in the broader economic environment. Therefore, it is not only the objectives of the dominant ecosystem actors, that by default affect the DLT ecosystem evolution, but also the incentives of the niche players that are being affected by the external ecosystem environment and in turn have an impact on DLT ecosystem evolution. One company might belong to several ecosystems and its contribution to the evolution of the DLT ecosystem might be impacted by its relationship with entities external to the ecosystem.

Technological change is an evolution factor to any ecosystem (Johannessen, Olaisen and Olsen, 2001), let alone to the DLT ecosystem, where technology lies in the heart of the value creation mechanism. Technological changes might take place either in the DLT itself or in technologies related to connections and protocols that affect ecosystem communication and collaboration. If technological changes are related to applications outside of the focal system, can provide an opportunity for DLT ecosystem expansion. More actors could be engaged through their interaction with the DLT ecosystem even if they do not belong in it.

Regulation is another factor of DLT ecosystem evolution. Regulatory bodies in many industries recognize the potential of DLT and in some areas, such as financial markets and commerce, the need of regulations seems to be imperative. Still, the intersection between commercial and regulatory motives impact DLT ecosystem evolution. The balance between enabling such an innovation and the risk of too much regulation or the attitude of regulatory bodies against DLT innovation potential affects radically the DLT ecosystem constitution. In that case multiple scenarios can emerge, such as regulations to reduce the investment spent on innovation or those that want regulation to accelerate innovation diffusions, since they enhance market stability, customer protection, reduced counterparty risk and consolidation of trust.

2.8 Business model innovation for DLT adoption

Technology itself has no singe objective value. When it is commercialized in some way by a business model then its economic value becomes apparent (Chesbrough, 2010). Although we will relate to business model literature, this study does not intend to propose another business model definition. However, we will briefly refer to the basic notions of business model definitions. In general, there is no accepted definition of the term business model due to the inconsistent use of the term (El Sawy and Pereira, 2013). The lack of definition consistency is clearly presented by Zott, Raphael and Massa (2011) and Morris, Schindehutte and Allen (2005) that reviewed 103 business model publications and concluded that a business model has been referred as a statement, a description, a representation, an architecture, a conceptual tool of model, a structural template, a method, a framework, a pattern, a plan and as a set. Two key business model studies of Chesbrough & Rosenbloom (2002) and Osterwalder et al. (2004), recognize the value proposition, the customer market segment, the value chain, the cost and profit structure, the strategic positioning of the firm in a value network and the formulation of a competitive strategy as the major functionalities of the business model (Chesbrough, and Rosenbloom, 2002; Osterwalder, Parent and Pigneur, 2004). Despite the ongoing debate on the essence and purpose of the business model there is an increased consensus among authors that it represents the value logic of an organization (Fielt, 2013; Osterwalder et al. 2005; Pateli and Giaglis, 2004; Wirtz, et al. 2016). It is generally accepted that value proposition, value creation and value capture are the fundamental pillars of any business model.

2.8.1 Business model and strategy

Despite the increasing involvement of authors with a strategy-oriented view, most authors recognize the intersection between business model and strategy. The intersection lies in the fact that business models bring together the internal perspective of the firm, such as resources and routines, with the external perspective, such as partners, markets and customer. In addition to that recent business model definitions and approaches address the business network with focus on the roles, interactions and relationships between network members (Fielt, 2013). In sum the business model considers a holistic description of company's activities in an aggregated form (Osterwalder and Pigneur, 2010). It articulates how a company goes to the market to implement a strategy. It is the link between the strategy and the operative implementation (Osterwalder, et al. 2005; Dahan, et. al. 2010; Baden-Fuller and Haefliger, 2013; Zott and Amit, 2010). A business model is a representation of the strategic choices that characterize a business venture (Morris, Schindehutte and Allen, 2005). Additionally, a business model may have no comparison to existing businesses. A business model answers the question of how the provided benefits of an opportunity flow back into company into the form of revenue (Schallmo, 2013). It does not assess the attractiveness of the opportunity.

We adopt the ecosystem perspective for the business model that organizations need to consider when they participate in the DLT ecosystem. Papanikolaou. Angelis and Moustakis (2023), *critically examine three business model types that demonstrate similarities with the business model that an organization needs to adopt in order to fit in the DLT ecosystem characteristics and explored the main attributes, similarities and differences between each one of the network, digital and information business model types against the DLT business model. Researchers concluded that although each one of those types demonstrates some resemblance with the DLT business model there are* *critical parameters that are not addressed or are partially met. Comparison results are depicted in Table 4.*[16]

In alignment to the most influential business model definitions of other authors, value creation, value proposition and value capture are the most commonly accepted dimensions. (Chesbrough, 2006; Osterwalder and Pigneur, 2010; Johnson,2010). Furthermore, there is the need to include the value network dimension in our study, due to the inherent characteristics of DLT and the fact that supply chain collaboration is a key driver for improved overall performance. Under that perception in our research, we adopt the Velu (2018) 4Vs approach that adds the value network dimension on the top of, the dominant in literature, value proposition, value creation and value capture business model dimensions. [17] Value network dimension depicts the role of the focal company and its partners in the networked environment. That approach emphasizes actor relationships and complementarities at network level and how do they contribute into enabling the transfer of technology's core technical properties to benefits for customer via markets. Gassman et al (2013) employ a conceptualization of 4 central dimensions found in almost all business model generic studies. That are: Who is the customer? What is offered to the customer or else what is the Value proposition? How is the value proposition created or else how is the value chain being built? Why is the business model financially viable or else how is the revenue created ? The latter is described as Value dimension by Gassman et al (2013).

---

[16] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023.Unique or adjustable business model for DLT? Journal of Business Models, Vol 11, https://doi.org/10.54337/jbm.v11i1.7149

[17] Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

Business model types relative to DLT ecosystem and their main attributes		DLT Business Model attributes that differ
Network Business Model	Coordinated cooperation between a finite set of parties that promote long-term strategic cooperation	DLT ecosystem actor relationships can be cooperative, competitive and/or co-opetitive
	Value creation in organization's strategic business net	DLT ecosystem expands beyond the strategic business net of each one of its members
	The scope is to gain or sustain competitive advantage through information access or technology	Information access is a value generator but the objective is not necessarily to gain competitive advantage
Digital Business Model	Platform organizes the wealth creating activities	DLT architecture sets the boundaries of value creating activities but does not organize them
	Customer, value, partner and financial dimensions are imposed by platform characteristics	Value creating system is affected by the platform but is not relied on it
	Enterprises compete digitally with their content, customer experience and digitized platforms	DLT actors do not necessarily compete on any of these traits.
	Supplier, omnichannel, modular producer and ecosystem driver are the business model categories based on a "know-your-customer" perception	Only the platform provider in the DLT ecosystem may fall into one of those categories without the need of "know-your-customer" perception
		Transaction validator actors perform a specific role that is not related to the platform provider business model
	Role of complementors to digital or platform ecosystems	There is not any such equivalent role in the DLT ecosystem
Information Business Model	Explains how information is collected stored and delivered internally and externally	Interconnectedness and interdependency is supported and powered by information system integration but value capture, creation and delivery is only partially defined by the architecture.

Table 4: Comparison of DLT business model attributes with other business models (Papanikolaou, Angelis and Moustakis. 2023. Unique or adjustable business model for DLT?)

2.8.2 What drives DLT business model innovation

There is a lot of debate in literature around the business model transformation notions such as innovation, change and reinvention. The debate is mainly related to the approach adopted around the definition and the purpose of business model definition. The consensus about the dynamic nature of the business model is what actually blurs the lines between those three business model transformation notions. Business model reinvention is related with new sources of sustainable competitive advantage that are caused by disruptive innovation (Voelpel, et al., 2004). When non-trivial changes of at least two business model elements are implemented, we usually talk about business model change. In addition to that, when novel configurations of resources and transactions are implemented to create new markets or serve current markets, then we talk about business model innovation (Bock, A.J. and Gerard G. 2018). Business model innovation is also associated with the capability to commercialize new ideas and technologies or to depict the variations on a generic value chain (Magretta, 2002; Chesbrough, 2010). In any case, DLT brings fundamental changes in the way that value is exchanged, the way the transactions that are executed among ecosystem actors, that way that ecosystems interact, the relationships among ecosystem actors and the way that resources and capabilities change based on capture of new knowledge.

DLT is an innovation based on digital technology that drives value creation and capture mainly through its innovative transactional proposal on value object exchange. Seeing DLT architecture as a network organizational factor we can assume that it sets the growth perspectives and potentially and boundaries of the network. Consequently, we could assume that digital business models emphasize the technological aspect or the innovation as an input for value creation, value capture and value proposition. The networked and the ecosystem perspective of DLT is related to the inherent characteristics of technology. Collaboration between actors and the fact the interconnected actors create value for actors, as defined by Moore (1993) as the central idea in business ecosystems notably defines the ecosystem nature of the DLT business model.

2.9 Trust in DLT interconnected supply chain

Although supply chain efficiency is key factor of any high performed business, in manufacturing industry that factor is highly critical. In manufacturing companies supply chain management affects the way that manufacturers interact with their suppliers and customers, impacts the production process inputs needed and to a large extend defines organization's costs and profitability (Al-Shboul, et al 2017; Lawrence, 2011). Demanding customers and complication of products require several stakeholders not only to transact with manufacturer's supply chain but also to collaborate effectively and efficiently. It is rare that one company is responsible for the entire conceptualization, engineering and manufacturing of a particular product (Ulrich and Eppinger, 2003). Consequently, with so many actors involved and given the complication of the products manufactured, the significance of supply chain management for manufacturing companies becomes apparent. The intricacy of manufactured products, the need for synchronization among all interacting parties, the complexity of the production processes increases supply chain reliance on technology.

In DLT network, peer-to-peer transactions among its members are the driving force of the value collectively created by its members. Due to the inherent characteristics of DLT, actors create value for actors. Under a supply chain context, manufacturers exchange tangible and intangible value assets through DLT transactions with their direct and indirect direct partners. That is also the case among actor members that lie beyond their core business and extended enterprise level of the ecosystem they are involved (Moore, 1993). Information, data, knowledge exchange as well as monetary, service and goods transactions powered by DLT, involve manufacturer's interactions with potentially all its end-to-end external entities interconnected to its supply chain. Decentralization, immutability, increased supply chain visibility and transparency promised by DLT adoption, under a supply chain context (Ferreira, J. et al. 2019), set the basis for many forms of value creation for each individual network member. Trusted and previous unknown actors co-evolve capabilities and have the opportunity to collaborate, deliver goods and services more efficiently due to the benefits promised by the new types of transactions. Similar to the business ecosystem set up, DLT actors create value for actors, while at the same time they maintain their roles in the ecosystem and their loose interconnection. The business ecosystem approach that needs be conceptualized for a DLT network of interacting actors is also supported by the fact that in both formats the large number of interconnected participants and their interdependence for their mutual survival are among their foremost key characteristics (Iansiti and Levien, 2004).

Trust should be recognized not only as the outcome but also as the driver for DLT adoption. The former is validated by the fact that unknown to each other ecosystem actors, with no establish relationship, have the opportunity to collaborate with a high degree of confidence that opportunistic behavior is prevented (Angelis and Ribeiro da Silva., 2019). Data openness, transparency and visibility promised by the nature of DLT transactions, allow organizations to establish trusted relationships. Direct evidence, or else direct trust as mentioned in trust literature (Marsh, 1994), is supported by the decentralized way that data are kept, shared and accessed, without the need of any intermediaries to validate their trustworthiness. Based on one of the most cited model of trust in organizations (Mayer, Davis and Schoorman, 1995), we recognize competence and integrity as the key trust dimensions. Those dimensions can be under mutual and continuous assessment and evaluation by all interacting, parties, since DLT provides the necessary data visibility and transparency required. However, trust is also the key driver for DLT adoption. In a highly dynamic environment, relationships among actors are subject to change between competitive, co-opetitive and cooperative forms of relationships. On the top of that, these behavioral shapes among ecosystem actors coexist in the ecosystem.

2.10 Trust in Make-To-Order in-house supply chain operations

Literature recognizes trust and an important antecedent of inter-organizational network formation that affects productivity, supply chain collaboration and consequently affects firm performance positively (OECD, 2014; Lusch, 2011). When low level of trust among interacting parties is demonstrated then DLT is an ideal option to fill this gap. Without diving deep into the theory of trust, it is worth mentioning that the core essence of trust under a supply chain context lies in the relationships and data exchange aspect.

Literature recognizes trust as a key factor in developing supplier-customer relationships, while the fact that trust is recognized as necessary for collaborative relationships underlines its importance for smooth collaboration among organizations in-house supply chain interacting entities (Sahay,.2003; Uca, et al. 2017). Customer and supplier need a shared view of the actual supply situation and that resonates trust as a prerequisite for cross-organization collaboration at supply level through data exchange, data openness and visibility. However, this is also the case that supply chain efficiency focuses on collaboration of entities and departments internal to the company. In both cases, trust comes with transparent processes. Operational and strategic information exchange is significantly related to supply chain performance. Best-in class internal supply chain competencies require organizations to develop and adopt more structured collaboration models by enabling true data transparency (Ramayah and Roaimah, 2010; Hu and Monahan, 2015).

The Make to order (MTO) manufacturing process is initiated only after a customer order is received. In literature various MTO models are presented, mainly based on when the production starts in relation to the demand visibility e.g., assembly kick off, design development or initiated with material receipt (Mingzhen, 2021). For the purposes of this study under the MTO context we will consider that the basic design is available when an order is placed and at that point the production is initiated yet from the material receipt. In the MTO supply chain the customization needed, in terms of end product specifications due to product mix variations, makes the Order Penetration Point (OPP) to be positioned at the raw material level. However, due to our assumption of design availability when orders are visible, we exclude the supply chains that design processes take place downstream to the OPP. In literature the there are various approaches regarding the order penetration and the decoupling point (Mason-Jones and Towill, 1997; Burbidge, 1989). The latter is the point at which actual demand, in the form of a customer order that triggers purchase order, penetrates upstream the supply chain. The OPP is mainly seen as the point that actual demand is visible.

It is worth mentioning that material and information flow are the key attributes which formulate the principles of a hybrid supply chain. Another dominant approach in literature supports that there is not one but of two decoupling points, which are the material and information decoupling points (Christopher and Towill, 2000). The first is indicative of the inventory buffer point and is usually related with postponement manufacturing strategies. The latter is supported by the information-enriched supply chain concepts, that position it at the point where actual demand information is visible. In our case study there is no late configuration strategy adopted and we will consider that there is one decoupling point which is the same to the OOP. It indicates the point where demand is visible, the raw material order is triggered and consequently coincide with the point at which buffer inventory should be kept. OPP positioning indicates the degree of customization and defines the manufacturing strategy and the product routing on the shop floor (Spring and Dalrymple, 2000; Hendry, Kingsman and Amaro,2003). MTO indicates a degree of customization that, based on a dominant literature approach, is classified according to the production volume and the product variety in two main categories, the Repeat Business Customizers (RBC), such as the home appliance industry companies and Versatile Manufacturing Companies (VMC) (Amaro, Hendry and Kingsman, 1999). The difference is that the latter customize products not on a continuous basis with some predictability but in smaller batches with more complex PPC solutions required, due to high level of product variety and demand variability.

In that part of our study, we focus into the supply chain operations that take place internal to the company. Apart from the in-house logistics operations, which include the handling of material and products within own organization including the functions of assembly and maintenance, under the in-house supply chain context we encompass all the manufacturing and in-house production related activities. Apart from critical supply chain processes, such as inventory control, quality control, inbound receipt and procurement, we will particularly focus into the (PPC) activities. PPC lies in the heart of our research, since it is the heart of the in-house supply chain value adding activities in a manufacturing company (Bandyopadhyay, 2019). PPC embraces planning material requirements, demand management, capacity planning, scheduling and sequencing of jobs and intends to reduce Work in Progress (WIP), minimize Shop Floor Throughput Times (SFTT) and lead times, lower stockholding costs, improve responsiveness to changes in demand, and improve Delivery Date (DD) adherence (Stevenson, Hendry and Kingsman, 2005). The diversity of manufacturing environment characteristics and in particular at the shop floor configuration level, the customization promised are determining factors of PPC configuration and applicability (Soman, et al., 2004).

Although literature proposed various shop floor configurations, which are differentiated based on the direction of the material flow, in our case study we will consider the General Flow Shop (GFS). Under that context, although flow shop demonstrates a multidirectional routing, work still travels in one dominant direction and jobs are allowed to visit a subset of work centers, permitting limited customization, relevant to a RBC (Stevenson, Hendry and Kingsman, 2005; Kan, 1976). All PPC approaches proposed in literature can be effective under the right job shop conditions. Since there cannot be an one-size-fits-all PPC approach, that will guarantee supply chain efficiency we consult the literature that defines job shop configuration and company size as the key determinants for PPC options (Stevenson, Hendry and Kingsman, 2005; Plenert, 1999). We will therefore particularly consider the Work Load Control (WLC), Constant Work In Process CONWIP, Enterprise Resource Planning (ERP) with special attention to Material Resource Planning (MRP) / Manufacturing Resource Planning MRP II, Paired Cell Overlapping Loops of Cards with Authorization (POLCA), Theory of Constraints (TOC), which are proposed in literature as the key PPC alternatives for the MTO sector under the constraints of GFS and RBC as illustrated in Figure 5. Through our case study approach, we expect to meet most of those approaches and evaluate the degree to which they are adopted, wondering if and how they leave space for DLT adoption.

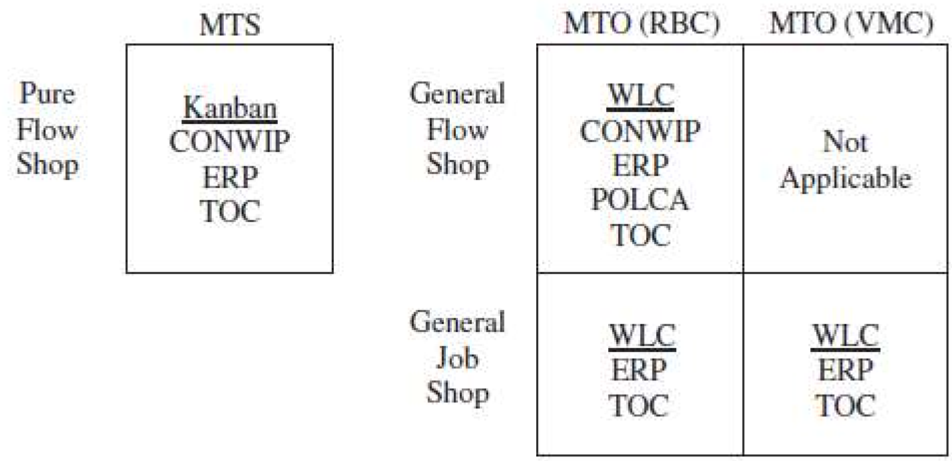


Figure 5: System selection matrix presenting PPC alternatives for the MTO (Stevenson, Hendry and Kingsman, 2005)

3. Methodology

To investigate both our research questions, that evolve around why and how questions which will reveal explanations of real-life key events, we selected inductive, interpretive, qualitative case study method, based on Eisenhardt (1989) and Yin (1994) approach. Our inductive approach driven by the little knowledge on the researched topic is based on the tactic of figuring out patterns that emerge from the concepts captured, organize them in 1st and 2nd order concepts and based on the aggregate dimensions that are distilled from the 2nd order concepts end up designing the process models that answers our main research questions' (mRQ1, mRQ2)insights (Gioia, Corley and Hamilton, 2013). Giving voice to top-ranking (elite) informants in decision making roles, that hold extensive and exclusive knowledge has been central in the interview process which has been the main source of evidence of our study (Richards, 1996; Vaughan, 2013). In addition to that the approach of admitting semi-ignorance of the literature at the data gathering and the initial data analysis phase, fulfills the two key conditions that lead to qualitative rigor in inductive research (Eisenhardt, 2021). Moreover, qualitative research rigor is demonstrated through the graphic representation of data structure configuration (Pratt, 2008; Tracy, 2010).

Yet from the identification of 1st order concepts the forced 'stepping-up' in abstractness has been driven by capturing the interpretations of the elite informants' insight. Although the 'semi-ignorance' of the literature allowed the researchers to avoid prior hypothesis and conformation bias we needed to set the boundaries conditions of the research that allowed us to focus on the most important issues and avoid excessive detours to lesser misinterpretation of informants' insights.[18] Although we defined a broad and loose framework in the interview process, we preserved flexibility to adjust interview protocol based on informant responses. In that way we ensured that we will not unintentionally fall into the trap to consult the literature too much or insist on a tight interview framework and consequently risk a transition from an 'inductive' to a form of 'abductive' research (Alvesson and Karreman, 2007).

As proposed in literature, the approach followed has a dual scope. To achieve enhanced analysis quality (Robert, 2018) and meet the necessary 'boundary condition'

[18] Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

for theory building based on qualitative research (Eisenhardt, 2021). To make this possible, authors recognized the risk that stemmed from the complexity and the expected limited or possibly skewed knowledge of the informants on the DLT under a supply chain concept. In the interview protocols, although researchers avoided to structure tight preconditions that would pre-empt or guide the 1st concepts captured, defined a broad and loose framework of interview variables that are directly related with DLT adoption. That are the notions of trust, as described based on the mode of trust in organization presented by Mayer et al (1995), data openness, business ecosystem expansion and actor relationship dynamics.[19]

DLT implementation enhances trust but finds ground for development in the case of low level or when decentralization is required (Lee and Pilkington, 2017). Although visibility of unique identifiers and related transactional histories raises privacy concerns (Beck, Müller-Bloch and King, 2018; Bφhme, et al. 2015), along with supply chain data and process transparency are the key elements for supply chain efficiency. Gaps in visibility and transparency could be overcome with solutions, such as DLT, or management and organizational best practices. However, when trust among interacting parties triggers the need for higher visibility and transparency, then we acknowledge them to be the major drivers for DLT adoption (Rückeshäuser, N. 2017). That is why, we direct our research both through the informant interviews and other sources of information, such as company documents, press releases etc., towards revealing trust issues, relationship and power attitudes of internal and external to the company entities which constitute the in-house supply chain mechanism.

3.1 Empirical setting

3.1.1 Multiple case study research for mRQ1 "What are the implicit effects in business model that stem from DLT adoption?"

To answer mRQ1, meaning "What are the implicit effects in business model that stem from DLT adoption" we adopted an inductive, interpretive, qualitative multiple case study method, Evidence derived from multiple cases are often considered more compelling and the overall multiple-case study is therefore regarded as being more

[19] Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

robust (Herriott and Firestone, 1983). To aim our understanding into what are the implicit effects of DLT to business model for manufacturing companies, we opted for a qualitative study. We adopted a process model building approach through a pattern matching analytical approach using constant comparison between the theory and data (Glaser and Strauss, 1967) and replication logic (Robert, 2018). Following the Eisenhardt method, to create a close fit among the constructs and relationships revealed in data and the supportive theory we examined each case as a standalone observation iterating the theory and data comparison for each case. In that way we followed the qualitative rigor path of theory building from multi case designs, as described in literature (Eisenhardt, 2021), where a replication and not a sampling multi case study logic needs to be met.

Although over the last years DLT receives significant attention due to its promise to change the way that organizations interact, exchange information and create value, it is still a technology in its primitive stage of development. Manufacturers are mainly at the phase of exploring DLT, mainly through proof of concepts and vast adoption is still not the case due to technology barriers. That leaves scholars with limited insight on DLT effects on business model and that is one of the reasons that the respective extant literature has paid little to no attention on that area. This status, based on literature (Eisenhardt, 2021), provides a fertile opportunity and sets the foremost theory building criterion based on qualitative research method. In our study we seek to explore the business model indirect effects based on the key attributes attached to the organization and the respective manufacturer's ecosystem through DLT adoption. Our little knowledge on that topic led us to pursue an inductive approach to identify the business model effects stemmed by the notions of trust, business ecosystem expansion and the respective relationships dynamics that are inextricably and foremost directly related to DLT adoption by a manufacturing company at supply chain level.

To emphasize and adjust the interview variables to the supply chain context of a manufacturing company researchers considered the segmentation of inbound, outbound supply chain partners, the customers and the rest ecosystem actors as the interview dimensions that need to guide the impact of DLT adoption exploration. To avoid an unintentional transition from an 'inductive' to a form of 'abductive' research and in order not to insist too much on a tight interview framework researchers followed the best practice, as recommended in literature (Alvesson and Karreman, 2007), to adjust the interview protocol based on informant resources.

3.1.2 Single case study research for mRQ2 "How DLT adoption causations at in-house supply chain level impact organization's business model?" and subRQ2.1 "To what extent could DLT adoption impact manufacturing leanness?'

To answer the second research question (mRQ2) of "How DLT adoption causations at in-house supply chain level impact organization's business model?", an inductive, interpretive, qualitative case study was selected, allowing aspects and factors derived from real life cases to drive our findings (Yin, 1994; Eisenhardt, 1989). DLT is in its primitive stage of development. Its adoption in manufacturing companies and in particularly at in-house supply chain operations has been a rare case. In the cases implemented has been mainly adopted under a proof-of-concept context, mainly for experimental purposes. Consequently, this gives us little to no knowledge on the need for DLT adoption at in-house supply chain level. On the top of that extant literature provides limited insight into the evaluation of DT at in-house supply chain level and its respective impact on the business model. Because we know little about that topic we selected to pursue our research inductively following a qualitative interpretive approach. Our scope is not only to surface new concepts but also to design the process model that answers our research question (Gioia and Pitre, 1990).

In the inductive approach followed it is essential to follow a tactic that captures emergent concepts which are new or produce new insights (Gioia, Corley and Hamilton, 2013). By capturing emergent concepts, figuring out patterns and organizing them into 1st and 2nd order concepts we end up revealing the aggregated dimensions that provide us the data structure basis to proceed further into process model development. We set up the framework of the semi-structured interviews in a way that we started by investigating the in-house supply chain causation and variables of trust and disintermediation in terms of information at in-house supply chain level issues among interacting parties.

This part of our research is based on a global home appliance original equipment manufacturer, hereafter called HA-OEM. Based on literature, we can generalize from a case study as long as principles generated by the case demonstrate an obvious relevance to some other domain (Gioia, Corley and Hamilton, 2013). Our research intent, through an inductive case, is to generalize to theory (Bansal and Corley, 2011), extracting transferable concepts and principles allow our findings to address a larger audience

(Lincoln and Guba, 1985). The selected manufacturer had to fulfill some basic selection criteria. Those criteria are related with supply chain efficiency and would indicate that the organization operates a high performing in-house supply chain and therefore applies in-house supply chain best practices and methods, proved through the respective Key Performance Indicators (KPIs) as well as high end supply chain strategies supported by high information system integration.

Our focus into the case study selection criteria stems from the need to make sure that the organization has taken all actions to resolve all potential issues relevant to the causation of DLT implementation. Although this may sound paradoxical, it reveals the grounded assumption that an organization that operates a high end, efficient in-house supply chain has resolved or at least has a mechanism to deal effectively and efficiently against all obvious in-house supply chain anomalies, that someone could claim to lay the ground for DLT adoption. In any other case, we could have been misled to falsely recognize as DLT in-house supply chain adoption drivers some indications, issues and challenges that could have well been met with classical supply chain practices, methods and strategies if applied. Simply put, to answer our research question (mRQ2) and generalize our findings we need to look into an organization that its key informants and researchers would agree into the conclusion that: "The organization operates at the high end and applies efficiently and effectively cutting-edge in-house supply chain best practices and strategies to deal with supply chain abnormalities, achieve continuous improvement and maintain supply chain performance high standards. However, specific causations might justify DLT adoption at in house supply chain level."

For the case study researched, attention had been given to organization's supply chain subunits or departments that interact with the in-house supply chain operations. Apart from the typical in-house supply chain and logistics operations such as PPC, inventory receipt and planning, logistics management and communication, we included data from departments and operations that intersect and affect in-house supply chain operational efficiency. By involving units of analysis at more than one level we designed an embedded case study (Robert, 2018; Gaya et al. 2016). Researchers' intention was to capture all aspects that impact in-house supply chain operation and would resonate DLT adoption. The selected manufacturer's embedded subunits, such as procurement, maintenance, machinery, quality control and engineering departments were picked based on their impact on supply chain operations. The latter has been investigated through an evolving interview process with manufacturer's elite informants.

To answer subRQ2.1, meaning "To what extend could DLT adoption impact manufacturing leanness?", researchers followed a mixed method approach comprised. This is composed of the exploratory qualitative inductive method, that generated the results of the mRQ2 and the participatory method that uses that results to further apply a scenario of DLT under the same case studied and quantify the potential leanness improvement measuring the total throughput time (TT). Mixed methods are suitable for researchers to combine qualitative and quantitative methods of data collection in a single study (Creswell,1999; Timans, Wouters, Heilbron; 2019). In our case qualitative indictive research, that had been used to answer mRQ2, allow us to understand DLT adoption causations under an in-house manufacturing supply chain context. Based on that findings we will further adopt participatory methods to generate the scenario that will eventually answer subRQ2.1. explaining the phenomena through numbers.
Participatory methods include the involvement of external scientist stakeholders in the scenario development process. The value of a participatory methods lies in the fact that they allow integration of different types of knowledge and perspectives to improve scenario development (Ernst et al, 2018). The need to combine researchers' knowledge on DLT with 'HA-OEM's' elite informants' insight on organization's manufacturing process makes participatory methods the ideal option to develop the scenario of DLT in terms of its impact on organization's manufacturing leanness. Scenarios are neither predictions nor forecasts (Brewer, 2007) and thus claim to describe but not accurately predict the future state (Ernst et al, 2018). Scenario planning is about defining a different reality, understand diverse paths and measure how the respective environment will change (Meissner and Wulf, 2013). In our case under the assumption that DLT will be adopted at in-house supply chain and no other lean technique, such load leveling, material supermarket (S/M), Kanban post etc., will be applied and under the conditions of unchanged production volume plan and unchanged PPC schedule, and we opt to measure if and how much manufacturing leanness will be affected, thus answering subRQ2.1.

Productivity, quality, work-in-progress inventory (WIP), floor space use and throughput time are the most commonly used shop floor metrics for an organization to measure its manufacturing leanness (Ortiz, 2007; Womack and Daniel, 2010). Most improvements of significance in manufacturing operations have involved substantial reductions in production cycle times and throughput times (Plossl,1988). Throughput time is a time it takes a product to flow down the assembly and manufacturing process (Ortiz, 2007) Moreover, based on literature, WIP inventory is a key determinant of manufacturer's throughput time (Hemalatha, Sankaranarayanasamy and Durairaaj, 2021; Crandall and Burwell, 1993). Based on Little's law WIP inventory equals Throughput-Rate multiplied by the TT (Spearman and Hopp, 1998). Therefore, by improving WIP inventory levels manufacturers achieve better throughput time. Since WIP and throughput time are not only key manufacturing metrics but also closely associated we will focus our research efforts into elaborating on mRQ2 findings and measure total throughput change through the reduction of WIP after assuming DLT adoption under the same single case study as in mRQ2.

3.1.3 Case study selection criteria for mRQ2 and subRQ2.1

Given the fact that the embedded subunits need to be within or part of the original single-case (Robert, 2018) and to increase case study validity and transparency we expanded our research into 4 out of the more than 20 production plants of the HA-OEM organization, selected based on specific criteria. Those were that all 4 plants needed to demonstrate similar production volume, manufacture the same group of products and be top PPC performers based on the HA-OEM group annual PPC annual evaluation. In that way we elevate research transparency, based on the fact that all HA-OEM group production plants follow the same production strategies principles, supply chain strategies and PPC system. Consequently, plants with same in-house supply chain, production volume and product characteristics would allow through the application of the same semi-structured interview protocols the replication of the study and reveal data patterns.

Based on literature, single case study is an appropriate design when the case meets specific requirements such as representing an extreme or an unusual case (Bφhme, et al, 2015). Under a MTO manufacturing context, we recognize five prerequisites for an organization to be an ideal candidate for a single case study research. That are: (1) to demonstrate top-notch in-house supply chain in terms of effectiveness and efficiency, (2) high information systems integration (3) be a large organization, (4) the absence of late configuration manufacturing strategy and (5) to belong in the lowest possible level of industry's regulation. If all five conditions are met, would justify the 'unusual' attribute of a single case rational. The first and second characteristic is necessary in order to avoid our research to identify as in-house supply DLT adoption drivers, supply chain inefficiencies that could have been dealt with the implementation of the appropriate supply chain strategies and manufacturing best practices. In short, the more efficient and high-end the in-house supply operation is, the more obvious the DLT adoption drivers will be. Our intention is to generalize our findings based on the assumption that, ideally, all possible in-house supply chain related deviations are solved without the need of DLT adoption. Studying a MTO organization with a top performing supply chain which applies effective and efficiently, high end supply chain techniques and strategies we are more confident that the identified in-house supply DLT adoption drivers will not overlap with any effective solution or workaround proposed by extant supply chain best practices and strategies. High information system integration that supports supply chain operations and strategy ensures that ensures information flow flaws due to system inefficiencies We will further elaborate in the following chapter how HA-OEM meets this single case study selection criterion.

Research question have been selected to be investigated through a case study of a large organization instead of a SME. Based on literature, SMEs find it difficult to implement most of the strategies of SCM applied in large enterprises (LE), either due to lack of understanding, implementation feasibility and awareness or because those are just not suitable and implementable (Ramakrishna, 2016).Someone could argue that supply chain challenges are largely the same for all businesses, big and small and that results driven from case study based on a LE cannot be generalized to SME. SMEs deal with less complex supply chains and those enterprises might feel more confident about the trust level among their in-house supply chain entities, the visibility and transparency of data exchange and transactions, due to the shorter supply chain depth and length. However, looking into the in-house supply chain of a LE we expect to discover a wider spectrum of cutting-edge supply chain strategies and methodologies supported by more up-to-date technological developments (Wook, 2006). This approach is expected to lead our inductive research to reveal 1st order concepts, that will not include in-house supply chain DLT adoption drivers which might coincide with challenges addressed by the extant supply chain strategies and methodologies. However, we acknowledge that we cannot completely generalize results driven by a LE case study analysis to SMEs, since minor supply chain irritations for big businesses, can be gigantic hurdles for SMEs that struggle to surmount and not vice versa (Huin, Luong and Abhary, 2002). In short, our research findings could be generalized to a large extend to SMEs, since we do not expect SMEs, compared to LEs, to reveal more complex supply chain challenges that could have been holistically addressed by high end manufacturing supply chain strategies and methodologies. HA-OEM is one of the leading companies in the sector, ranked among the top nine (9) home appliance manufacturers rated by revenue (Statista, 2019). Operates more than twenty (20) production units around the world with revenues of over five (5) billion US dollars ,in a multi-billion dollar industry with global sales amounting to more than 270 billion euros in 2019 (Statista, 2023). HA-OEM employees over 20.000 employees and obviously lies in the LE category based on the E.U. criteria that determine the company size (European Commission. 2003).

Late configuration, or else postponement, manufacturing strategy would be a high supporter of DLT adoption at in-house supply chain level. Researching the drivers of the in-house supply chain adoption we focus into the internal to the organization supply chain entities' interactions and the intersection of those entities with actors external to the company. In the case where postponement strategies are applied, the point that actual demand is visible, or else the order penetration point would severely impact the inventory kept at the decoupling point and the internal manufacturing operations downstream to that point (Christopher and Towill, 2000; Mason-Jones and Towill, 1997). Trusted information exchange, data visibility and transparency between internal and external to the company entities and external would make DLT adoption an ideal candidate for supply chain efficiency. For instance, trusted data access and exchange, through DLT adoption, among PPC department, at in-house supply chain level that receive the market data and marketplace entities that transmit it, would make DLT an idea solution or operational efficiency. Hence, we do not select an organization that applies manufacturing postponement strategies, since we do not want to research the case of a situation with an obvious DLT in house supply chain adoption causation. HA-OEM does not apply any late configuration manufacturing strategies.

The later justifies the researchers' judgment not to select for case study research an organization from a highly regulated industry. In regulated industries supply chain visibility on trusted data is vital. On the top of that there is a requisite level of visibility that need to be met (Klüber and O'Keefe, 2013). The fact that government or industry regulators require additional trusted supply chain related information and on the ground that in-house supply chain DLT adoption ensures real time visibility of tamperproof data, provides a strong causation for DLT adoption in highly regulated industries. Based on reports home appliance manufacturing industry is not among the 10 most regulated industries both in E.U. and U.S.A (McLaughlin-Sherouse, 2014; Al-Ubaydli and McLaughlin, 2014).

3.1.4 How does the case study selected for mRQ2 and subRQ2.1 meets the selection criteria.

In house supply chain KPIs related to productivity, quality, inventory, PPC consistency and other PPC related KPIs have been found to be maintained at high levels for at least 3 consequent years in all 4 production plants that were included in our research. We focused to those KPIs that constitute a group of KPIs which are considered by literature as the most prevalent MTO in house supply chain family of metrics (Stevenson, Hendry and Kingsman, 2005; Gopal and Thakkar, 2012). The fact that most interviewees at all managerial levels reported high level of trust into their partners and the fact that quality control department has not been overshoot as proved by the respective quality control and deviation metrics and the informants' answers, enhanced our confidence for a controlled, streamlined, smooth in-house supply chain operation.

In addition to that, the organization applies periodical audits that not only cover all supply chain level and processes but are organized in a way that all the 'plan-do-check-act' philosophy is followed for each audit at each production plant (Srivannaboon, 2009). Moreover, organization's headquarters, plant supply chain departments, internal and external auditors are involved to ensure the credibility and transparency of audits that are based on the most up-to-date audit standards. In each HA-OEM plant ISO audits are performed every 2 years, quality assurance, risk assessment and production system audits are performed every 3 months with 5S and lean assessment and audits to be performed on weekly basis. All audits cover the full spectrum of potential in-house supply chain inefficiencies and deviations and continuously trigger the respective corrective and preventive actions. Apart from audits, HA-OEM has implemented Six Sigma techniques in all of its production plants. With the empirical and statistical methods that constitute the Six Sigma techniques, which target to identify and remove the causes of defects and minimize the impact of variability in manufacturing (Tennant, 2001), we recognize the HA-OEM focus on process improvement strategies. We are therefore confident that due to the combination of multilevel, frequent, well-structured audits and the continuous improvement strategies applied, quality of in-house supple chain output process is not only closely monitored but brings to surface as much recognized supply chain inefficiencies as possible. The bottom line is that the organization has the mechanism to identify supply inefficiencies and the cutting-edge methodology to deal with them. This makes the researchers confident that all findings related to in-house supply chain DLT implementation will stand separately and completely cut-off from extant manufacturing management practices related to supply chain improvement.

The corporate strategy of HA-OEM to maintain high level of internal information system integration provides the necessary basis for information sharing and effective coordination among departments. With almost all processes to be executed paperless, through a high-end modern ERP solution, the user grouping observed regarding he access of other high end supplementary information system solutions streamlines the data collection, reporting, analysis, sharing and visualization of all necessary information among in-house supply chain departments. Information system integration effort is a continuous process for HA-OEM also in areas that supplement supply chain process, such as the integration of Product Information Management (PIM) and Digital Asset Management (DAM) as part of the content management system operated. On the top of that, HA-OEM has taken the endeavor to digitalize and simplify the communication between the company and its partners, to enhance partnership transparency and long-term collaborations. To a large extend, the value stemmed from DLT implementation lies in the information exchange dynamics among interacting entities (Xu, Chen and Kou, 2019). Literature clearly depicts the relationship between trust, information sharing and information exchange reciprocity (Kaushik, et al, 2017). Taken the latter as given within an in-house supply chain context, we were strict into selecting an organization that demonstrates really high level of information system integration. That was the case for HA-OEM, since this was not only an observation noted by the researchers but had also been reflected by organization's elite informants, through their high level of confidence and trust into the information kept internal to the organization, at least at plant level.

Manufacturer's focus to applying top-notch production system practices and high-end manufacturing strategies is clearly reflected through the fact that a custom HA-OEM Production system has been developed and applied in all production units. HA-OEM Production system is based on the Toyota Production System (TPS) and encompasses the respective principles, methods and tools customized for the 'HA-

OEM' production system attributes. Demand oriented production, zero defects, avoiding waste, robust product phase-in / phase-out are some of the HA-OEM production system pillars, in line with the respective TPS philosophy, that targets to increase factory capacity. In addition to those high-end manufacturing practices, other best practices as recommended in literature have been implemented. HA-OEM implements value stream mapping and design, to improve the whole and not just optimize the parts (Rother and Shook, 2003) has also adopted lean techniques that refer to just -in-time manufacturing, Kanban, S/M, milk run techniques that are practiced as part of the lean manufacturing process (Ortiz, 2008). In addition to that, standardized work as part of manufacturing procedures have been implemented, so that precise procedures can be set up that will allow HA-OEM to make products in the safest, easiest, and most effective way (Mor, et al. 2019). PPC lies in the heart of the high-end manufacturing practices applied by the manufacturer, since material requirements planning, demand management, capacity planning and scheduling are typical functions of a PPC system (Stevenson, Hendry and Kingsman, 2005). HA-OEM applies all PPC key methodologies from a MTO point of view, based on literature, such as MRP II, Optimized Production Technology (OPT), Workload Control (WLC), Kanban/Just In Time (JIT), Gemba Walk and Theory of Constraints (TOC) to achieve supply chain efficiency by reducing Work in Progress (WIP), minimizing Shop Floor Throughput Times (SFTT) and lead times lower stockholding costs, improve responsiveness to changes in demand, and improve Delivery Date (DD) adherence (Zapfel and Missbauer, 1993; Gelders and Van Wassenhove, 1981).

In addition to that, two out of the four production plants included in our survey gained the "Best PPC System" recognition over the last 5 years, among all 20+ production plants of the HA-OEM group, based on the PPC audit reports and the respective annual PPC evaluation results at plant level. The latter along with the fact that lean manufacturing management practices in combination with almost all available PPC pull schemes are applied, makes us confident that in-house supply chain operation of HA-OEM manages to keep shop floor under control and achieve manufacturing efficiency through the application of all, based on extant literature, cutting edge and methodologies and practices (Hoop, and Spearman, 2004; Womack, Jones and Roos,1990; Suri, 1998). In that way someone could not claim that there is high possibility the interviewed HA-OEM informants to refer to issues that could have been resolved with manufacturing practices not applied due to ignorance of those methodologies and practices. It is obviously expected that informants and researchers will identify space for improvement of applied manufacturing systems and practices, but it is also expected that in-house supply chain DLT implementation drivers will be distinct from those that are referred to the extant manufacturing practices improvement determinants.

In short, HA-OEM relies in its integrated global supply chain to deliver customer promises. State-of-the-art in-house supply chain processes and optimally designed continuous improvement best practices allow the organization to operate an effective and efficient in-house supply chain. Manufacturing process efficiency is achieved through optimized procedures and workflows due to the use of modern methods, techniques and tools. The HA-OEM 's work processes and the implementation of a high-end quality management system are organized as effectively as possible. The advanced structure of the latter facilitates the continuous improvement of organization's processes. High information system integration strategy and interconnected digital solutions do not only facilitate data access and information exchange but also enhance decision speed and reinforce decision makers' trust to data kept internal to the company. Those characteristics allow the researchers to be more confident that the concepts identified through the inductive research will be free of the assumption, or at least significantly reduce the risk, of considering that in-house DLT adoption 1st order concepts, are related with actions that the organization could have taken, based on the extant literature supply chain and manufacturing management best practices.

3.2 Data collection

3.2.1 Multiple case study data collection for 1st main research question (mRQ1)

The main source of evidence of the multi-case study research that intends to answer 1st main research question (mRQ1), meaning "What are the implicit effects in business model that stem from DLT adoption ?" consists of semi-structured interviews with elite informants of 25 large manufacturing companies established in 8 European countries. Between December 2020 and April 2021 two rounds of remote and on-premises interviews, lasting approximately 90 minutes each, have been conducted with each elite informant from each one of the 25 manufacturing companies as presented in Table 5.

Apdx Table 2, in Appendix section, illustrates the relationship between the business model, supply chain and interview dimensions that have been considered for interview design.

Based on literature six supply chain structures describe the range of possible operations: engineer-to-order (ETO), buy-to-order (BTO), make-to-order (MTO), assemble-to-order (ATO), make-to-stock (MTS) and ship-to-stock (STS) (Hoekstra, 1992; Naylor, Naim and Berry,1999; Yang and Burns, 2003). BTO and ATO could be considered that are closer to MTO, since orders generated through actual consumer demand and the order penetration points lies in the upstream of the supply chain for STS one could say that it is closer to MTS since the decoupling point, or else the order penetration point is located at finished goods. MTS and MTO are considered the most prevalent among other supply chain strategies and for our case selection criteria we will only consider manufacturing companies under the MTS or MTO set up. The reason that we leave out the ETO from our sample supply chain framework is that the decoupling pint is located at the design stage (Gosling and Naim,2009), meaning that customer order triggers order-specific engineering. Based on literature ETO requires different information management strategies than the other supply chain forms (Donselaar, Kopczak and Wouters, 2001).

DLT and information management are inextricably linked and for a supply chain strategy, meaning ETO, that is much differentiated in terms of information management DLT adoption needs to be researched separately. Without going into many details on ETO it is indicative that based on literature, information and production systems for an ETO supply chain should allow for basic information to be incomplete, partly inconsistent, or not up to date (Wortmann, 1995).

Research question (mRQ1) has been decided to be investigated through case studies of large enterprises (LEs), following the characteristics of LE as described in literature (Ramakrishna, 2016). LEs demonstrate higher supply chain complexity, interact with more business ecosystem actors and develop relationships either from a dominant or a non-dominant position. Under that conditions we expect elite informants from LEs to have a high-level overview of a broad spectrum of options, actions and strategies implemented. This would allow the researchers to shed light to a wide range of supply chain activities intentions and results driven by DLT adoption. On the top of that based on the DLT supply chain projects running up to the date this research is conduced, it is the LEs that drive the developments.

Elite informants included senior, head and c-level supply chain managers, in order to capture a multifaceted view of the discussed themes. The spectrum of the themes discussed required high-level overview and active engagement of the interviewees into strategic supply chain corporate decisions. During the first sitting, with the support of an interview guide, 26 open ended questions were asked and a conversational manner had been assumed (Rubin and Rubin, 2011). Interview questions are presented in Apdx Table 1 found in Appendix. The themes discussed during the 1st round of interviews set the trust and data openness as the basis of supply chain decisions and the relationships with manufacturer's direct and indirect supply chain partners. We continued by keep setting as the basis of the semi-structured interview (Weiss, 1994), the notions of trust, supply chain collaboration and data openness. We expanded the conversation into supply chain decisions that involve actors, that lie beyond the core business and extended enterprise business ecosystem layers, as described by Moore (1993), such as regulatory bodies, competitors, customers etc.

After the first phase the researchers identified themes emerged in data and some repeated patterns started to appear. The purpose of the second round of interviews was focused into corroborating the patterns and findings initially emerged. To reduce bias, the second round of interviews took place one month after the first. Interviewees where asked to provide a fresh commentary on the findings so that theoretical saturation could be reached. In short, the second round of interviews had been conducted with the support of an adjusted interview protocol based on themes emerged in data after the first round of interviews (Robert, 2018). To maintain consistency, the lead author conducted all interviews. If one interviewee failed to comment on one aspect of the pattern discussed, in particular when findings discussed had not been supported by his/her insights identified in the initial interview, then further informants from the same company were identified by snowballing techniques. Key informants were asked to recommend colleagues who had a thorough insight on the aspect discussed (Kvale, 1996).

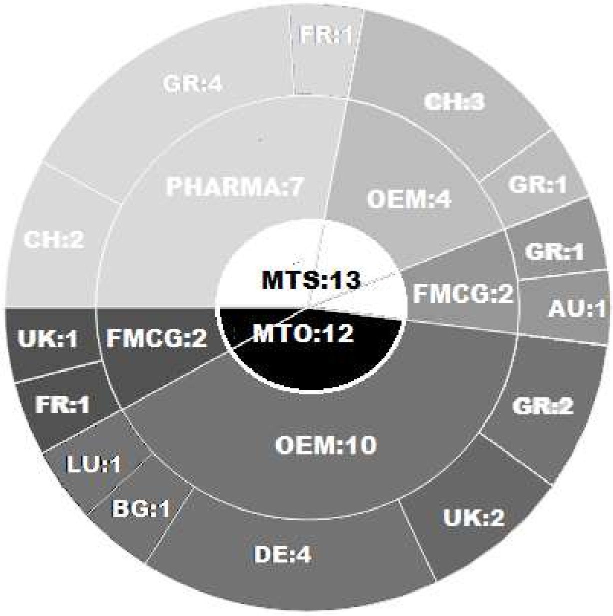


Figure 6: Interviewed firms per supply chain type and industry for multiple case study research (mRQ1)

Country	Industry	Role	Phase 1	Phase 2
CH	Pharma	Contract Manufacturing Supply Manager	OPM	RI
CH	OEM	Sr. Manager Global Project and Processes	RI	OPM
UK	OEM	Manufacturing and Supply Chain Manager	OPM	RI
CH	OEM	Production Manager	OPM	RI
UK	OEM	Manufacturing Manager	RI	RI
GR	FMCG	Head of Supply Chain	OPM	OPM
GR	Pharma	Head of Supply Chain	OPM	OPM
FR	Pharma	Supply Chain Manager	RI	RI
GR	Pharma	Warehouse & Distribution Head	OPM	OPM
GR	Pharma	Head of Supply Chain	OPM	OPM
DE	OEM	Sr. Supply Chain Manager	RI	RI
DE	OEM	Supply Chain Manager	RI	RI
DE	OEM	Supply Chain Manager	RI	RI
GR	Pharma	Head of Operations	OPM	OPM
AU	FMCG	Head of Operations	RI	RI
FR	FMCG	VSM Leader	RI	RI
BG	OEM	Operations Manager	RI	RI
LU	OEM	Head of Supply Chain	RI	RI
CH	OEM	Head of Supply Chain	RI	RI
GR	OEM	Head of Supply Chain	OPM	OPM
CH	Pharma	Supply Chain Manager	RI	RI
DE	OEM	Supply Chain Manager	RI	RI
GR	OEM	Supply Chain Manager	OPM	OPM
GR	OEM	Supply Chain Manager	OPM	OPM
UK	FMCG	Supply Chain Manager	RI	RI

OPM: On Premise face to face Meetings
RI :Remote Interview
OEM: Original Equipment Manufacturer
FMCG: Fast Moving Consuming Goods Manufacturer

Table 5: Data collection id for multiple case study research (mRQ1)

The second phase of interviews had been completed when data collection and analysis revealed patterns, concepts and themes that were subject to little change when new information were produced (Guest, Bunce and Johnson, 2006). Figure 6 and Table 5 illustrate research identity characteristics. For confidentiality reasons participant identities and company names are not disclosed. Although data analysis had been majorly based on semi-structured, researchers followed the qualitative research best practice as illustrated in respective qualitative research literature and employed external sources of evidence (Gioia, Corley and Hamilton, 2013). Secondary data had been used in particular at the case selection phase. Those resources allowed the researchers to of the complexity the depth and the recent developments on the supply chain structure of the organizations selected for the research. In addition to that during the first stage of the data collection interviewer could gain a clearer understanding on the organization's overall supply chain operation and raise questions adjusted to organizations supply chain profile as discovered through the secondary resources. Electronic documentation collected from multiple sources such as corporate websites, corporate reports, annual reports, press releases, facts and figures from publications on databases had been used for that dual purpose.

3.2.2 Single case study data collection for 2nd main research question (mRQ2)

To answer the 2nd main research question (mRQ2), meaning "How DLT adoption causations at in-house supply chain level impact organization's business model?" we draw on extensive data collected during interviews conducted in four phases. Key informants were located in four production plants, three in E.U and one overseas. In one E.U. production plant, hereafter called Plant A, interviews were conducted on-premises. Interview questions and interview design are illustrated in Appendix in Apdx Table 4 and Apdx Table 5 respectively. Plant A that has been the Plant which provided the main source of data through on-premises visits had gained, once over the last 5 years (2018-2022), the "Best PPC System" recognition, among all HA-OEM production plants. Between Sept 2021 and March 2022 20 semi-structured interviews with 18 informants located into four selected HA-OEM production plants and 3 on premise visits to one selected, E.U, based production plant, where researchers conducted multiple source data collection.

In Phase 1, the first visit to the selected production plant was intended to identify if all four case study selection criteria were met to proceed further. Three semi-structured interviews of approximately 90 min each, with the plant's Head of Supply Chain, Operation Manager and Production Manager were conducted, combined with visit to all plant supply chain and production departments. At that phase informants were asked high level questions related to the manufacturing strategy, in-house supply chain operation and structure. The scope of the semi-structured interviews along with the respective internal documents, corporate presentations delivered by HA-OEM managers, the supply chain KPIs presented, the presentation of selected audit results and the internal evaluation procedures, were necessary to ensure that the organization meets the manufacturing strategy and high-end in-house supply chain operational efficiency criteria set by the researchers. At that point researchers agreed with the first senior level interviewees, that although the scope of our research and our ultimate research question (mRQ2) had been inevitably revealed and discussed with them, this would not be the case with the informants further involved in the research. Enforcing ignorance of the theoretical background of the research to the interviewers would eliminate the risk to mislead them and guide the answers. That would eventually lead to a deviation of the character of the study from the inductive form of the research, particularly since DLT is by default not a widely comprehensive topic.

In Phase 2 the second round of data collection included two more onsite visits in the selected Plant A. At that phase approximately 60min semi-structured on premise, face to face interviews were conducted with each one of the informants. Interviews were combined with visit to the respective plant departments, where necessary, to observe the real job performed and the processes of the departments that acted supplementary or were intersecting with the in-house supply chain. From the production and assembly lines to departments such as maintenance, machine shop, quality control, PPC and the engineering department, on the spot observation of the processes executed and short discussion with the employees, supplemented the main phase of our data collection. At that phase apart from the many short discussions conducted with the employees acting on the real-job, eleven semi-structured face to face interviews with the Supply Chain, Production, Maintenance, Engineering, Quality Control, Warehouse and Production Manager as well as with the VSM Leader, Demand Planner, Inventory planner and PPC Associate, were conducted. Those informants that had already been involved in Phase 1 of data collection had prepared and presented more in-depth data from various internal resources as discussed during the first visit.

Before we conduct the second visit in Plant A, researchers had downloaded and screened all available free on web and related to the research information for the organization, such as annual reports, supply chain related information available on the corporate website, press releases, facts and figures from publications databases and corporate reports. Information collected was presented and discussed with the respective senior level managers interviewed interviews during the second visit in Plant A. Although semi-structured interviews had been the main source of data for the research, based on qualitative research best practice we employed multiple data sources such as written and electronic documentation and participant observation. The last two data sources served as supplementary sources of understanding processes, key perspectives and their presentation to various constituencies and discrepancies among informants (Jick, 1979; Miles and Huberman, 1994). Associated secondary data, such as electronic documentation collected from multiple sources, had also been used for the triangulation of the findings as the interview process progressed.

Following the Lincoln and Guba's (1985) guidelines for "purposeful sampling" in choosing our informants (Lincoln and Guba, 1985), we started interviewing mid to senior level managers that would hold a high-level overview of the HA-OEM management practices, procedures and strategies related to the research question (mRQ2) discussed. To dive deeper into processes and details we needed to involve employees of other departments or same department junior to mid -level ranked informants, especially those with substantial expertise not possessed by others. In that case a snowball technique was used, asking for interviewers' recommendation as to who could best explicate the processes of our interest (Kvale, 1996). To maintain consistency, the lead author conducted all interviews. Interviews became progressively more structured as themes emerged in data and interview protocol had been adjusted based on informant responses to preserve flexibility (Gioia, Corley and Hamilton, 2013). Researchers ensured progressive focusing to targeted interviews as themes emerged in the data.

After the 2nd phase, researchers identified themes emerged in data and some repeated patterns started to appear. The 3rd phase includes remote interviews with elite informants of three other HA-OEM production plants, meaning Plants B, C and D. Data that demonstrated the fact that case study selection criteria were met for those plants had been provided from the initial HA-OEM plant involved in the research. Interviews with totally six elite informant, meaning the Head of Supply Chain and the Operations Manager for each one of the three HA-OEM production plants was intended to identify whether saturation would have been reached when comparing interview data with data collected from Plant a during data collection Phase 1 and 2. New informants needed to be interviewed up to the point that further data collection and analysis would not yield any further explication of the given theme (Glaser and Strauss, 1967). Since the supply chain structure of HA-OEM group plants had been presented to be the same for all plants, researchers decided to focus into senior level managers directly related to the heart of supply chain operations. In that case the interviews were longer than in any other case lasting approximately 2 hours each and for logistical reasons had been conducted remotely. This phase apart from the iterative process of simultaneously collecting data, analyzing them and seeking new informants on the basis of prior elite informants' interviews also targeted to enhance the validity of the research. Comparing and analyzing information deemed from the informants interviewed in HA-OEM Plant 1 against the information gained from the interviews and presentations Plants B, C and D was intended to validate, enrich or question findings and establish trustworthiness and authenticity in findings of the study.

Researchers target was to reach saturation by identifying that "new information produces little or no change to the codebook" (Guest, Bunce and Johnson, 2006). Before we reach to that point and after analyzing the data of an evolving sample of informants, a last round of written and remote contacts, Phase 4, with selected senior managers interviewed in earlier phases has been decided. The purpose had been to clarify inconsistencies appeared in part of data and clear up information and data critical to pattern formation, that based on the initial analysis demonstrated some ambiguity. Data cleaning phase took place one month after the 3rd phase of data collection intending to reduce data collection bias. Table 6 summarizes all data collection efforts until theoretical saturation was reached.

		Phase 1	Phase 2(*)	Phase 3	Phase 4
Plant A(**):	(PA01) Head of Supply Chain	OPM			
	(PA02) Operations Manager	OPM	OPM		
	(PA03) Production Manager	OPM	OPM		
	(PA04) SC Manager		OPM		
	(PA05) Maintenance Manager		OPM		SRC
	(PA06) Enginering Manager		OPM		SRC
	(PA07) Quality Control Manager		OPM		
	(PA08) Value Stream Mapping Leader		OPM		
	(PA09) Demand Panner		OPM		
	(PA10) Inventory Planner		OPM		
	(PA11) PPC Manager		OPM		
	(PA12) PPC Associate		OPM		
Plant B:	(PB01) Supply Chain Manager			RI	SRC
	(PB02) Operations Manager			RI	
Plant C:	(PC01) Head of Supply Chain			RI	SRC
	(PC02) Operations Manager			RI	
Plant D:	(PD01) Supply Chain Manager			RI	SRC
	(PD02) Operations Manager			RI	

OPM: On Premise face to face Meetings & Interviews
RI:Remote Interview
SRC: Short Remote Communication
(*) Two visits for on premises obervation of real time Supply Chain/Manufacturing Department operations
(**) Three on premise visits

Table 6: Data collection id for single case study research (mRQ2)

3.2.3 Single case study data collection for subRQ2.1

To answer the subRQ2.1, meaning "To what extend could DLT adoption impact manufacturing leanness?" we collected data based on HA-OEM elite informants interviewed for mRQ2 data collection. Data collection for subRQ2.1 had been initiated after results from mRQ2 had been extracted and presented to elite informants of all H-OEM plants that participated in subRQ2.1 data collection interviews after the conclusion of all data analysis phase of mRQ2 In that new part of the research, we followed the same setup in terms of HA-OEM production plants engaged and period of data collection as in the case of data collection for the purpose of mRQ2. There had been only one exception in elite informant synthesis engaged which is, that for Plant B, C, D instead of interviewing the Supply Chain Managers we interviewed VSM Leaders. That had been a consciously choice, since researchers decided that TT and WIP inventory would be indicators of DLT in house supply chain adoption potential impact to manufacturing leanness and that VSM would be the main part of data analysis methodology, as explained in detail in next section.

1st order concepts derived while researching for mRQ1, as presented in Figure 8, had been the basis of Phase 1, 90 min semi-structured interviews conducted during three onsite visits in Plant A, while researching for subRQ2.1 Researchers decided to present 1st order concepts, since there had been generated based on interviewees interpretation regarding in-house DLT adoption causation and not based on further analysis by researchers. In that way and based on interviewees understanding on DLT adoption researchers considered that each informant could easily realize the link between his/her own saying, as reflected in 1st order concepts and in-house supply chain DLT adoption causation. Consequently, interviewees could easier understand the scenario investigated for subRQ2.1 purpose. The scenario presented to each one of the interviewees of Plant A and in the next phase also to Plant B,C,D informants could be summed up in the following phrase " Assume that we adopt DLT everywhere in 'in-house supply chain' and without applying any other lean technique we need to define and measure what will be affected that will impact manufacturing leanness and more specifically WIP inventory and TT' To increase research validity data collected based on that scenario from research conducted onsite at Plant A had been shared, with Operations Managers and VSM Leaders of Plant B,C, D in data collection Phase 2. Due to arguments raised feedback from Plant B, C, D had been reshared with VSM Leader and Operations

Manager of Plant A in data collection Phase 3 so that data will be redefined. Data collection efforts for subRQ2.1 are presented in Table 7.

		Phase 1(*)	Phase 2	Phase 3
Plant A(*):	(PA01) Head of Supply Chain			
	(PA02) Operations Manager	OPM		OPM
	(PA03) Production Manager	OPM		
	(PA04) SC Manager	OPM		
	(PA05) Maintenance Manager	OPM		
	(PA06) Enginering Manager	OPM		
	(PA07) Quality Control Manager	OPM		
	(PA08) Value Stream Mapping Leader	OPM		OPM
	(PA09) Demand Panner	OPM		
	(PA10) Inventory Planner	OPM		
	(PA11) PPC Manager	OPM		
	(PA12) PPC Associate	OPM		
Plant B:	(PB02) Operations Manager		RI	
	(PB03) Value Stream Mapping Leader		RI	
Plant C:	(PC02) Operations Manager		RI	
	(PC03) Value Stream Mapping Leader		RI	
Plant D:	(PD02) Operations Manager		RI	
	(PD03) Value Stream Mapping Leader		RI	

OPM: On Premise face to face Meetings & Interviews
RI:Remote Interview
(*) Three on premise visits for data collection and process observation

Table 7: Data collection id for single case study research (subRQ2.1)

Data collection served a dual purpose. The first had been to identify which production processes will be affected under the scenario of DLT adoption that impacts only the information flow and not the material flow aspect of the production and second to quantify the impact on the WIP inventory between processes. Since HA-OEM keeps records and for any respective data depicted on VSM current state and recognizing that to come up with new accurate measurements based on our assumptions is not an easy task, researchers asked for an estimated range of change between ± 5%. As soon as Plant A, B, C, D Operations Managers and VSM Leaders agreed on the estimated range of WIP change per case, researchers validated the proposed numbers through literature. As presented in data analysis section, based on the reason that stimulated WIP inventory change, there are studies found in literature that have calculated the expected performance improvement that had been found to be within the WIP inventory change resulted through suRQ2.1 data analysis findings.

3.3 Data analysis

Our analysis approach, for both case studies based on qualitative data inductive analysis best practice proposed in literature (Glaser and Strauss,1967; Lincoln and Guba,1985), required data collection and data analysis to evolve coincident. During the 1st phase of data analysis, yet from the initial interviews of the first round of interviews, raw data analysis revealed an increased number of 1st order categories based on grouped data. First order coding, through the selected use of interviewees' words and phrases from a section of data, led to labeling and further categorizing each section based on their similarities and differences. As data collection and data analysis evolved in parallel after the completion of the 1st round of interviews the open-coding practice not only revealed the 1st order distilled categories but kept them at a manageable number. The axial coding process of the 2nd phase of the inductive analysis refers to the grouping of 1st order concepts into higher order themes, and identification of their connections that depict their linkages (Strauss and Corbin, 1998). The 2nd order themes that emerged at this phase from the links and patterns observed among the 1st order concepts are related to the 'how' and 'why's' of the case study, based on the pattern matching analytical technique as proposed in qualitative case study analysis literature (Robert, 2018).

3.3.1 Trustworthiness of data

To ensure trustworthiness of data we collected data from multiple sources and followed a "recursive, process-oriented, analytic procedure" (Locke, 1996), which included coincident data analysis and data collection. The process has been continued until theoretical saturation has been met. Interview transcripts, notes retrieved from onsite observation and other documents collected, were managed through the RQDA qualitative data management coding software. In Appendix we illustrate the coding categories (Apdx Figure 1, Apdx Figure 2), coding, and categories (Apdx Figure3, Apdx Figure 4) plot sample (Apdx Figure 5, Apdx Figure 6) in RQDA both for mRQ1 and mRQ2 based on interview transcripts collected at the data collection phases. Senior level informant follow-up approach was selected to further clarify the data when ambiguity had been observed (Lincoln, Y. and Guba. E. 1985). Emerging patterns have been discussed among researchers with the engagement of a researcher, not involved in the study, though familiar with the respective DLT, trust and business model theory to gain outsider's perspective on data analysis before the process model building. Interpreting informant terms has been initially done by the leading author but to avoid differentiation in informant terms interpretation and to review open coding findings all authors have been engaged. Authors interpreted data independently and the synthesis of all authors' perspectives and arguments had been evidenced before 1st order themes validation (Bartley and Hashemi, 2021). In the case of arguments on coding results, authors revised the data. When extra information and clarification on raw data had been needed, the same follow up questions had been addressed to the same level senior level elite informants.

3.3.2 Multiple case study data analysis for mRQ1

Regarding mRQ1, "How's' are related to how, under a supply chain context, DLT adoption drivers would affect the supply chain dimensions of supply chain inbound and outbound partners, customers and other ecosystem actors. Moreover, 'Why's' are related to why DLT adoption would lead to certain results related to business model decisions. When 2nd order themes seem to emerge, data collection proceeded with the second round of interviews, where the 1st order concepts and the emerged 2nd order themes had been discussed. After the point where the 2nd order themes along with their respective linkages to the 1st order concepts have been crystalized, theoretical saturation has been reached. In the next phase researchers followed iterative analysis of data while contrasting the current literature and refining the emerging themes and patterns by revisiting single cases (Eisenhardt, 1989; Eisenhardt and Graebner, 2007).

That led to further aggregation of conceptual categories to 12 aggregate dimensions. In the final data analysis phase, researchers consulted business model literature to reveal the linkages of the aggregate dimensions with the factors that eventually revealed the DLT indirect effects to the business model. This step has not been a further aggregation of the 'how' and 'why' but targeted to link the aggregate dimensions with the activities that impact the business model. The graphic representation of data structure, along with the linkages with the business model related activities, as visualized in Figure 7, demonstrates the qualitative research rigor (Pratt, 2008; Tracy, 2010).

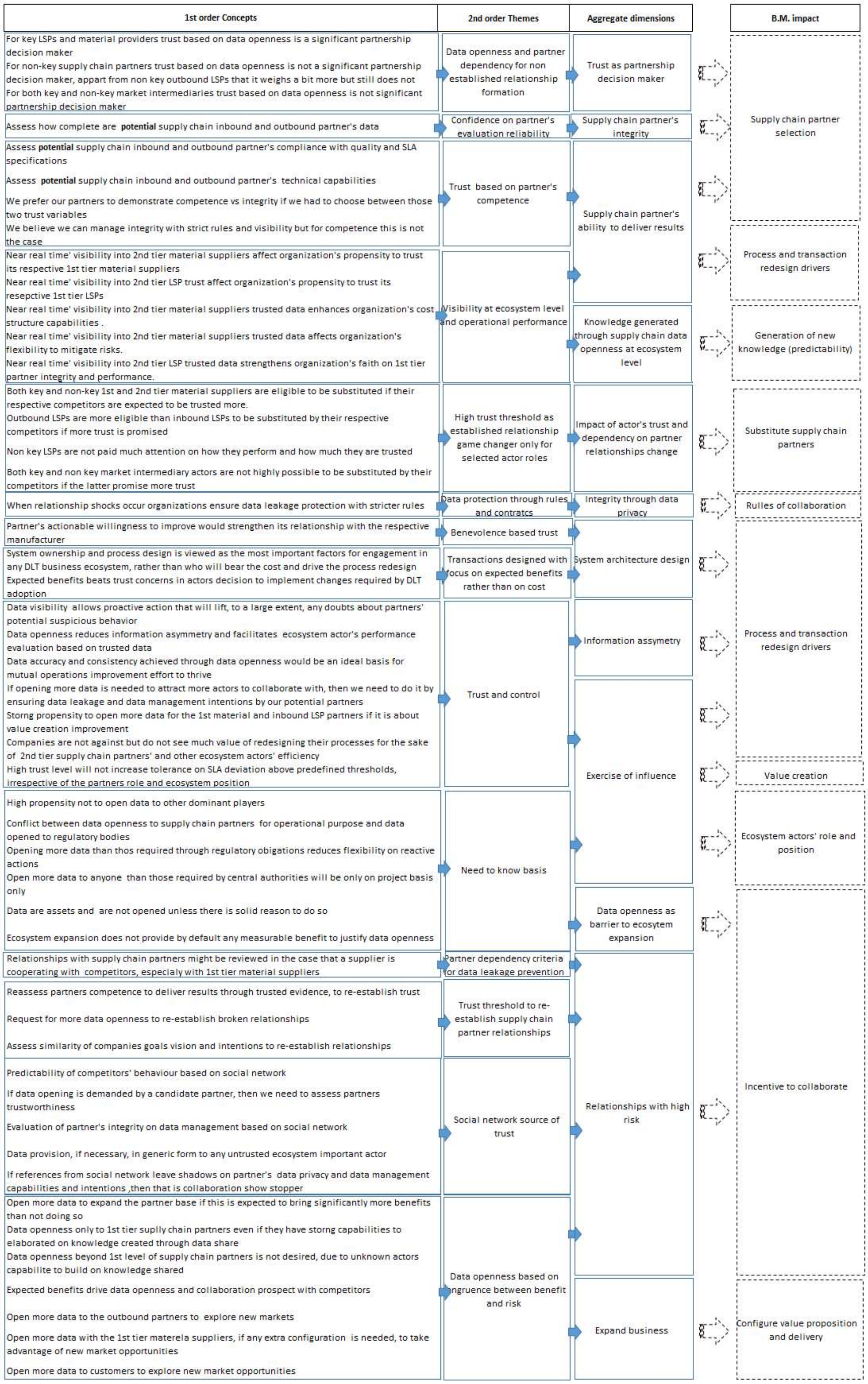


Figure 7: Multi-case study research data structure for mRQ1

3.3.3 Single case study data analysis for mRQ2

The 1st step in data analysis has been to analyze all raw data and group them into categories. The challenge of this phase is that already from the first interviews, 1st order categories seem to emerge. That number seems to increase as the data collection process evolves. Before we label distilled categories, we need to seek for similarities and differences among the categories and end up reducing them to a manageable number. The 2nd step involves the axial coding process (Strauss and Corbin, 1998). This step refers to 1st order concept grouping and the identification of linkages and relationships between them. At this step we assemble the 1st order themes into higher order themes drawing connections to depict that linkage. Links and patterns among 1st level empirical themes lead to the distinct concepts, that group them to conceptual categories. With the 3rd step of our analysis, we conclude data structure as illustrated in Figure 8. At this phase we are trying to subsume the nine (9) 2nd order themes into five (5) 3rd order theoretically rooted aggregate dimensions using insights from the theory (Gioia, Corley and Hamilton, 2013). Data structure provides a graphic representation of the analysis progress, from raw data to terms and themes and displays the linkages between the different levels of our analysis. The inductive model that is grounded in data, as exemplified by data structure, needs to be supplemented by an analysis of the weight of each one of the business model dimensions in regard to its impact into the source of the aggregate dimensions, meaning the 1st order themes. Therefore, in Figure 8 we also demonstrate the impact of each one of the 1st order themes that emerged on the business model dimensions of value creation, value proposition, value capture and value network.

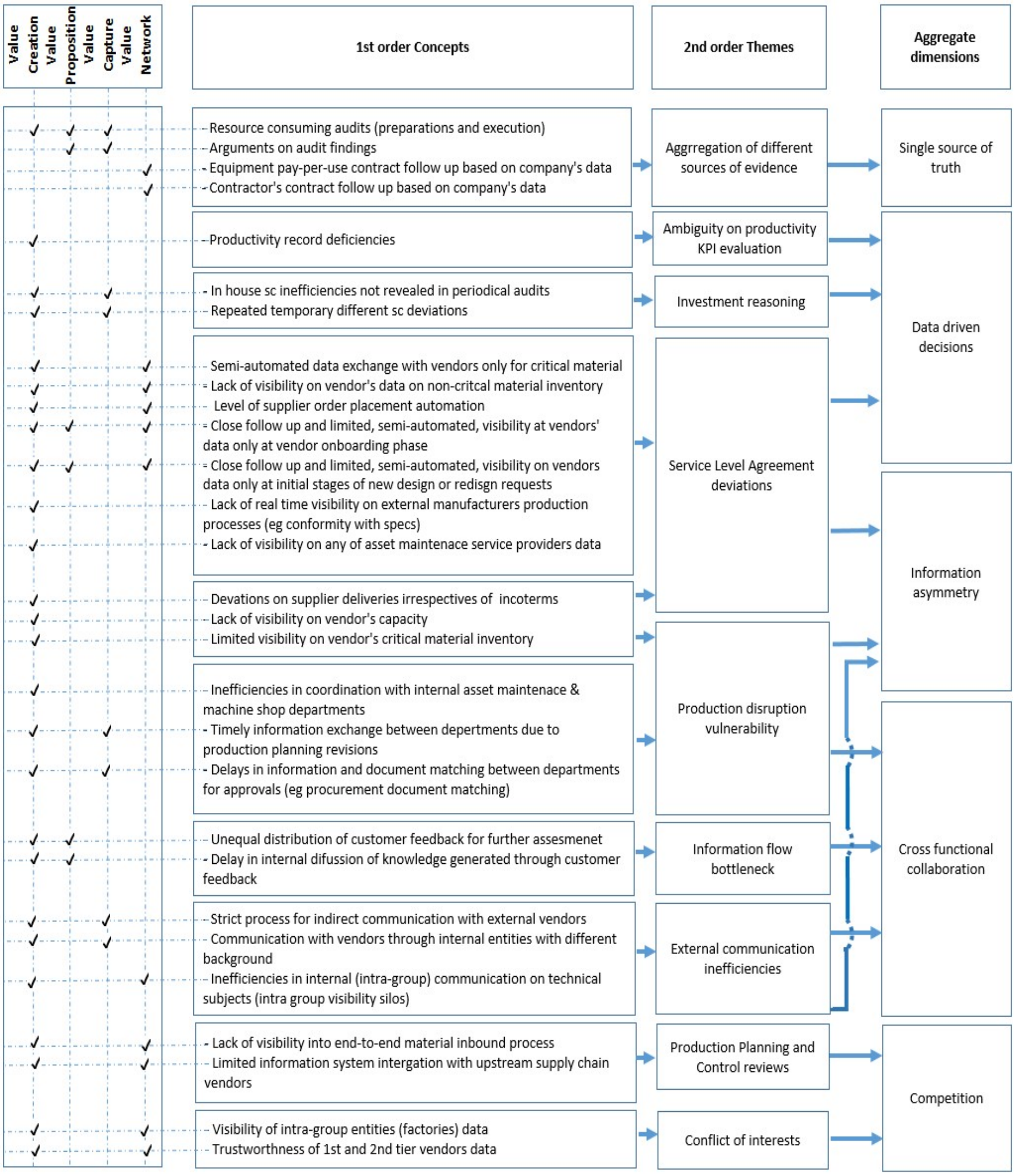


Figure 8: Single case study research data structure for mRQ2

3.3.4 Single case study data analysis for subRQ2.1

In 1st phase of data analysis, we opt to define which in house supply chain processes will be affected under the scenario of DLT adoption in every process within the 'in-house supply chain', without applying any other lean technique and what stimulates that change. Near- real time visibility, transparency of trusted information or data that is exchanged or needed to be available end to end within the manufacturing processes is the focus of our scenario. Based on that scenario, Plant A informants had been interviewed to depict which 1st level order concepts could impact any parameter of the production material flow. Based on interviews' answers researchers noticed that all HA-OEM informants tended to distinguish the 1st order concepts into those that would indicate DLT impact on production material flow under conditions of unexpected disruption and those that would impact production material flow under normal conditions, as presented in Table 8. It is indicative that for the first case we received answers such as: *"Yes I could see the impact of DLT but only in the case that something unexpected happens (PA08, PB02, PC03, PD03"* For our analysis purpose, researchers decided to focus on the cases of the second category, meaning DLT impact under normal conditions. Transferability is among the fundamental characteristics that a qualitative study should meet to allow results generalization (Smith, 218). Although unexpected production disruption reasons are standardized, we consider that evaluating DLT impact on production leanness supports way more the transferability of results to other manufacturing settings 'under normal' conditions compared to setting that demonstrate similar production disruption causations. Tha latter could be an opportunity for further study to extend the limits of current research. Therefore, the case of investigating DLT impact under normal condition has been selected to provide the necessary input to proceed in the 2nd phase of sub RQ2.1 data analysis.

1sr order concepts of inhouse s.c DLT adoption	Production flow impact
Resource consuming audits (preparations and execution)	no
Arguments on audit findings	no
Equipment pay-per-use contract follow up based on company's data	no
Contractor's contract follow up based on company's data	no
Productivity record deficiencies	unexpected disruption
In house sc inefficiencies not revealed in periodical audits	no
Repeated temporary different sc deviations	no
Semi-automated data exchange with vendors only for critical material	unexpected disruption
Lack of visibility on vendor's data on non-critcal material inventory	unexpected disruption
Level of supplier order placement automation	unexpected disruption
Close follow up and limited, semi-automated, visibility at vendors' data only at vendor onboarding phase	unexpected disruption
Close follow up and limited, semi-automated, visibility on vendors data only at initial stages of new design or redisgn requests	unexpected disruption
Lack of real time visibility on external manufacturers production processes (eg conformity with specs)	unexpected disruption
Lack of visibility on any of asset maintenace service providers data	normal conditions
Devations on supplier deliveries irrespectives of incoterms	no
Lack of visibility on vendor's capacity	no
Limited visibility on vendor's critical material inventory	no
Inefficiencies in coordination with internal asset maintenace & machine shop departments	normal conditions
Timely information exchange between depertments due to production planning revisions	unexpected disruption
Delays in information and document matching between departments for approvals (eg procurement document matching)	no
Unequal distribution of customer feedback for further assesmenet	unexpected disruption
Delay in internal difussion of knowledge generated through customer feedback	unexpected disruption
Strict process for indirect communication with external vendors	no
Communication with vendors through internal entities with different background	no
Inefficiencies in internal (intra-group) communication on technical subjects (intra group visibility silos)	normal conditions
Lack of visibility into end-to-end material inbound process	unexpected disruption
Limited information system intergation with upstream supply chain vendors	unexpected disruption
Visibility of intra-group entities (factories) data	normal conditions
Trustworthness of 1st and 2nd tier vendors data	unexpected disruption

Table 8: In house supply chain DLT adoption causation impact on production material flow

As mentioned in the respective data collection section we initially discussed the potential of applying the scenario. Next to that and after the 1st phase of data analysis we provided informants interviewed a structured approach for the interpretation of scenario data, and an empirical validation of expert evaluations, that is related to VSM methodology. Following those steps, based on literature, we meet qualitative data analysis consistency (Gambelli, Vairo and Zanoli, 2010). Phase 2 of data analysis for subRQ2.1 is related to the scenario that since production material flow will be affected after DLT adoption we need to identify which processes will be affected, what material production attributes will be impacted and how much. For that purpose, informants initially proposed the production processes that will be affected based in Table 8 findings and after that had been asked to identify what production flow attributes will be affected based on the scenario applied. This part of data analysis process occurred at Plant A and data collected have been analyzed by researchers and VSM Leader of Plant A. There have been afterwards shared for crosscheck and validation with VSM leaders of Plant B, Plant C and Plant D. Any arguments have been discussed with Plant A VSM Leader and Operations Managers. HA-OEM group of companies applies the value stream perspective for all its plants to improve production flow.

VSM is a tool that maps production flow based on material and information flow visualization, allowing the organization to designing value streams to reduce waste (Rother and Shook, 2003). VSM is a powerful tool since mapping does not only help spotting waste resources but also visualize how production flow path from customer to supplier is altered through changes applied either at material or information flow level of each process (Rother and Shook, 2003). The uniqueness of this tools is that it depicts the linkage between information and material flow. Information flow tells each process what to make or do next. Mapping is the technique that will allow this research to reveal how material flow is being impacted when information exchange changes due to DLT adoption (Hartmann, L., et al. 2018). What is unique on the proposed method is that the future state will not be designed based on the waste elimination target, that is the classical VSM approach supports, but will be simulated through subRQ2.1 scenario of DLT adoption applied of DLT.

Based on the existing VSM mapping of Plant A, see Apdx Figure 7, informants interviewed, identified the production processes affected based on DLT adoption scenario. Production processes proposed by informants interviewed have been initially validated by Plant A VSM Leader and researchers. Afterwards, those spotted processes along with Plant A VSM had been shared with Plant B, C, D VSM Leaders for extra validation. Tha latter raised no arguments at that Phase of analysis. At the next stage of analysis for subRQ2.1 For the validated production processes, Plant A informants have been asked to propose based on their records which production flow attributes would change and how much under and estimated range of change between ± 5%. As soon as data have been discussed and validated by Plant A VSM Leader and researchers, have been reshared for extra validation with Plant B, C, D VSM Leaders and Operation Managers.

In that phase, arguments that came up had been related with the range of the expected changes for specific WIP inventories. Those arguments had been discussed between researchers, Plant A VSM Leader and Plant A Operations Manager. After consulting the literature in manufacturing improvements expected based on information flow improvement, as referred in the respective subRQ2.1 Findings section, the final WIP inventory numbers have been agreed by all discussants. Final step of Phase 2 data analysis for subRQ2.1 entails the application of the proposed changes by to extant Plant A VSM, so that the new VSM, see in Apdx Figure 8 will be generated. New VSM illustrates all the changes in terms of the production flow attributes affected, and aggregated results for all manufacturing streams TT. subRQ.2.1 analysis steps are illustrated in Figure 9.

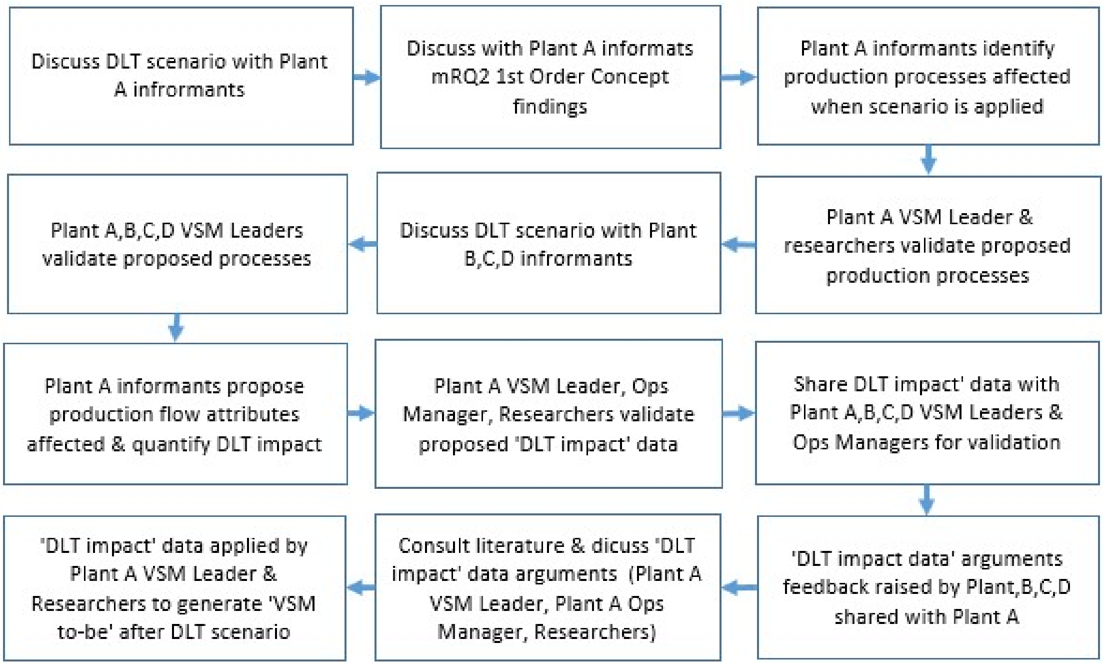


Figure 9: subRQ2.1 data analysis steps

4. Findings

4.1 Multiple case study research findings regarding mRQ1

In that section, we describe our findings that emerged from the data in relation to the ten (10) overarching themes we inductively identified and presented in Figure 7. regarding mRQ1 of" What are the implicit effects in business model that stem from DLT adoption". These themes refer to different types of intents and activities related to trust and supply chain collaboration that evolve during DLT adoption at supply chain level and are expected to impact manufacturer's the business model.

4.1.1 Supply chain partner's ability to deliver results.

Assessing partner's competence through visibility and access of trusted data is needed for the partner assessment process and sets a strong trust base between interacting parties before they establish their relationship. In addition to that, end-to-end supply chain visibility through DLT implementation and trusted data has been proven to be closely related both with manufacturers and its interconnected partners' operational performance.

4.1.1.1 Trust based on partner's competence.

All interviewees stated that their partner selection process is mainly oriented towards identifying partner's competence. Given the fact that cost parameters are within budget boundaries, the perspective of a manufacturer to establish partnerships is mainly defined by the future partner's capabilities and its promise to comply with expected standards. Both at supply chain inbound and outbound level, competence is the trust variable that needs to be assessed. Competence is an innate property that the trustee has no control over it (Ibrahim and Ribbers, 2009). All interviewees mentioned that no compromise with incompetent partners can be accepted. On the top of that, the cost of substituting a partner and especially a key partner, that has been proven not to meet expected standards has been clearly stated to be painful, with strong consequences to the manufacturer.

"If at any point of our supply chain partner evaluation process we feel that our future partner may not meet our standards, then this it is definitely a showstopper."

"We are willing to work together with our partners to solve problems and assist them to improve their performance but the bottom line is that we trust our data collected during the partner selection process to decide whether partner candidates can deliver or not based on our standards"

The importance of competence has been evaluated by the interviewees as a qualifier against the trust dimension of integrity. Based on those two fundamental trust variables, that set up the basis of the most widely cited models of trust in organizations, interviewers clearly qualified competence against integrity to the extreme scenario as if they had to select only one. Informants' replies revealed that strict rules, contractual clauses and well-established contractual agreements have the power to prevent undesired behavior that might stem from partner's integrity issues.

"Contractual terms and mechanisms that allow continuous evaluation of partner's performance have the power to prevent problems that might come up due to integrity issues. After all, we make it clear from the very beginning that integrity is not negotiable."

4.1.1.2 Visibility at ecosystem level and operational performance

Our data revealed that 'near-real-time' visibility is an important attribute not only for assessing 1st tier supply chain partners' skills and competence, as expected, but it is a strong indicator of partners' competence when visibility is extended beyond 2nd tier supply chain partners. Interviewees stated that although end-to-end visibility, in particular to logistic service providers (LSPs), is requested almost as a mandatory partnership condition, those partners that can provide real 'near-real-time' visibility, through their information system integration, had been historically proven to be more competent. The challenge though, of ecosystem visibility has been indicated to lie at the material suppliers. Information system integration and process redesign challenges are much higher when 'near-real-time' visibility is referred to the level of 2nd tier material suppliers and beyond. All interviewees stated, that although rare, if this status can be proven then it is almost certain that their direct 1st tier material supplier could deliver results as requested.

"For LSPs, end-to-end visibility is almost always requested and agreed. The challenge is how efficient and how time consuming is this process. With our partners we usually face the challenge of multiple system integration and communication loops that involve their partners and do not allow us to streamline the process"

"It is really rare to achieve 'near-real-time visibility' to manufacturing procedures with our material suppliers. For those that can provide that service we are absolutely confident that they can deliver even better results than expected"

4.1.2 Knowledge generated by supply chain data openness at ecosystem level.

DLT transactions reinforce knowledge creation and enhance member capabilities co-evolution. The way that data are accessed, the transparency and visibility demonstrated offer DLT network members the perspective to exploit data and create new data driven knowledge. In DLT networks future participants are incentivized both by knowledge creation prospects and access to collaborative knowledge promised to reinforce the validity of their data driven decisions and evolve their capabilities

4.1.2.1 Visibility at ecosystem level and operational performance.

First order concepts revealed that end-to-end visibility into material and LSP suppliers not only allow manufacturers to adjust their supply chain plans and synchronize their respective actions with the partners to achieve operational efficiency, as expected, but has been proven to be an important knowledge generator factor. Although 'near-real-time visibility' would be an ideal situation, access to trusted data deep in the supply chain at ecosystem level, would allow the manufacturer to analyze information collected, build on that and create new knowledge. Informants mentioned two main aspects on that prospect. The first is their capability to foresee deviations and risks and act respectively. The second is their opportunity to 'know more' about their own processes and best practices and improve. However, it is important to mention that the main doubt raised by interviewees has been how much they can trust that information. Meaning that, the further and deeper we look into the supply chain, the more actors are involved and more information bias is expected.

"The deeper we can look into the end-to-end supply chain operations, the more efficiently we can synchronize our actions to foresee and avoid and deviations."

"It is not only about elaborating on our partners' partner data but we need to make sure that we work on trusted data"

4.1.3 Supply chain partner's integrity

Apart from collecting information from social network about manufacturer's supply chain interconnected actors' behavior, access to complete trusted data and evaluation of data integrity has been proven to be a key indicator of partner's integrity. Consistency of partners words and actions can be proved through visibility of the respective data kept.

4.1.3.1 Confidence on partner's evaluation reliability

When future supply chain partners feel confident, they can meet tender requirements, they promise that they have the ability to deliver results requested, under specific norms and conditions and that no trust integrity concerns will come up. On the other hand, and the manufacturer has in place specific mechanisms to evaluate future partner's ability. Hence, integrity is based on intentional choices. Informants mentioned that evaluating partner's data integrity and completeness can be the same enlightening in their effort to evaluate overall partner's integrity overall, as to collecting information from social network. Data accuracy and consistency have much to reveal about the decision-making processes of the future partner. Apart from evaluating its capabilities, data integrity exposes candidate partner's attention to data driven decisions and the level of its internal organizational efficiency (Carling, 2019).

"Social network is an important source of information when we need to evaluate our partners' integrity but access to trusted data has much to reveal. Complete and well-structured data would prove candidate partner's intentions."

"Would you trust a positive recommendation, even from a trusted recommender, if your insights into your partner's data demonstrate low data accuracy and consistency? That would probably be too risky."

"After all, if you cannot prove it then it does not exist and that applies also to intentions and behavior."

4.1.4 Impact of actor's trust and dependency on partner relationships change.

Interviewees indicated that data openness triggers higher level of visibility and transparency but when established trust thresholds are not met, then the relationships among interacting entities are affected for specific supply chain roles.

4.1.4.1 High trust threshold as established relationship game changer only for selected actor roles

Trust among supply chain partners based on access to trusted data has been found to be a key driver of partner relationship change, irrespective of partners' interdependency. Based on our data, manufacturer's partnerships with their material suppliers and outbound LSPs have been proven to be prone to change, according to the trust level established due to data openness achieved. Irrespective of their inter-dependency, meaning weather they are key or non-key suppliers, when high trust thresholds are violated, then partner substitution dilemmas emerge. This is not the case though, for non-key LSPs and for market intermediaries that seem to be more resistant to trust level changes due to data openness. It is also important to mention that interviewers seem to recognize the added value of the end-to-end visibility for LSPs. However, when non key LSPs do not have the intention or even the ability to open their data, then this does not seem to change much in their relationship with the manufacturer.

"Ideally data openness would establish higher trust level with our material suppliers and would subjectively frame our decision to substitute one supplier with another that is believed to have the same performance but would allow us to access

its trusted data. May be that is one reason why accessing trusted data is still an issue and requires a big effort from our side with focus on selected critical suppliers."

"Market channels are not easy to be substituted since this might affect our relationship with the customer. So as long as they meet the targets set, we do not seek for extra transparency and visibility."

4.1.5 Trust as partnership decision maker

Trust is the social glue that holds business relationships together. For specific actor roles, data openness as a future partnership condition is considered as a mandatory prerequisite. However, access to trusted data and not data openness is the overall issue at stake.

4.1.5.1 1 Data openness and partner interdependency for non-established

Data openness and trust established among the manufacturer and its inbound and outbound supply chain partners, through the transparency and visibility created, facilitates the partnership decision making process. Yet, in general it is not a partnership decision making factor. Interdependence among actors seems, based on interviewees replies, to weigh more on that kind of decisions. Key LSPs and material suppliers seem to be expected, almost by default, to open more data to the manufacturer than any other inbound and outbound partner. The extant best practice for those two partner categories is that data openness, to the extent possible, is a prerequisite yet at the tender phase. Thereupon, all interviewees mentioned that a mechanism which would allow access to partner's data for those two categories would be what is missing. Manufacturers' intentions seem to converge to the following statement of an interviewee.

"No data openness for key inbound and outbound partners, then possibly no agreement"

Although almost all informants mentioned that data access and transparency is the new hot field of supply chain digitalization, it is still premature to demand it from all ecosystem partners interacting with their supply chain. On the top of that, interviewees seem to agree that it is too early to ask for it from their non-key suppliers. As for the market intermediaries at least for the mid to short term it remains a 'nice to have', rather than a 'must-have' capability.

"After all most digitalization efforts that are referred to opening and share our data have been implemented with focus into our key 1st tier suppliers."

4.1.6 Integrity through data privacy

Irrespective of the benefits promised by DLT, data privacy and the respective integrity are of major concern by both manufacturers and their future partners. DLT needs to demonstrate flexibility into opening or withdrawing specific pieces of information to the network based on the actor relationship dynamics. That adaptability has been found to incentivize to a massive extent all actors' intention to adopt DLT at supply chain level and be part of the respective business ecosystem.

4.1.6.1 Data protection through rules and contracts

Although visibility and transparency promised by DLT solutions, seems to be a major trust catalyst, our data indicate that data privacy and data leakage concerns are in the center of interviewees attention. When ecosystem relationship dynamics inevitably lead to relationship changes, then the need for data privacy seems to be of high priority. On the top of that, the more dependent a manufacturer is by its partner or the more dominant one of its partners is in the same ecosystem, the higher the importance for data protection. GDPR, Non-Disclosure Agreements (NDAs) and strict contractual agreements are almost always in place to prevent data leakage, especially to competitors. It has been clearly underlined by all interviewers that any mechanism dealing with data management and data openness needs to meet data privacy challenges, have the flexibility to combine off and on network data and allow data visibility cut off when significant relationships changes occur. For instance, in the case that a key supply chain partner exits the relationship established with the manufacturer and creates a partnership with one of the manufacturer's competitors.

"We cannot overlook data privacy for the sake of data openness benefits."

"In a highly dynamic environment our relationships are always subject to intentional or unintentional change. Our data are our assets and based on the relationship set up we need to adjust the level of data access and visibility."

4.1.7 System architecture design

DLT implementation would enable transparency on interacting parties' supply chain related activities that is expected to support their intentions to improve operations. Attention to transaction design has been found as a fundamental element of DLT design that would allow all interacting parties to realize the benefits promised by DLT implementation. Any architecture design gaps might destroy actors trust into the system and consequently make them skeptical to join the network, since cost and risk might outweigh the benefits.

4.1.7.1 Benevolence based trust.

When a tier 1, tier 2 or any other ecosystem partner underperforms then mistrust concerns raise, irrespective if this is a temporary situation or not [78]. The same applies when integrity issues come up and consequently trigger mistrust. Established partnerships signal, by default, that at least some level of trust had initially been in place. All efforts to reestablish trust, either through corrective actions that aim to improve performance deviations, or through behavior that will eradicate integrity issues that came up, need to be considers based on what some interviewees mentioned as "actionable willingness to improve". A mechanism, usually backed up by an information system, supports the monitoring of improvement efforts and allows decision makers, through measurable results, to continuously audit the progress achieved. The system architecture must be in position to facilitate efforts taken by both parties in a transparent way. When mistrust has been raised there is no space for misunderstanding, false data analysis and misleading conclusion. Transparency on any root-cause analysis, clear undisputable data along with clear intentions for improvement, are fundamentals in the trust restore-effort. Benevolence has been proven by our data to be the trust variable (Hofer, Knemeyer and Dresner,2009), that is not only impacted but has to be proven through transparent trusted transactions.

"When mistrust emerges, clear intentions proven through transparent undisputable conclusions is the key. There is no room for any error, even unintentional, until we reestablish trust."

4.1.7.2 Expected benefits vs cost for transaction design.

Any change in the way that companies interact, exchange and share information is a painful and resource consuming process. System architecture interventions that will holistic or partially change the data exchange process need a lot of attention to transaction design. According to our findings, manufacturers are willing to take that step, if the expected benefits overcome the data privacy concerns and they have the first say over the process design. The probability of the high cost of any such system architecture change or intervention, along with the prospect to share or roll over that cost to their partners have been discussed with the interviewees. The parameter of cost has been surprisingly found to be of much less importance than expected. The focus has been clearly stated to lie in the system architecture design. The latter is expected to allow the benefits of DLT implementation to be realized and is required to demonstrate some flexibility to meet all interacting parties' expectations and lift data privacy concerns.

"That kind of innovations must be carefully designed so that they meet our expectations and data management concerns. I am confident that this, rather than the expected total cost of the solution, would be the major challenge also for our partners who will be asked to get engaged,"

"It depends on the expected benefits. When we think of a new way to exchange and access data, I can think of some highly promising occasions that the benefits would overrule budget restrictions."

4.1.8 Information asymmetry

One of the major and stronger DLT adoption drivers at supply chain level has been proven to be the elimination of information asymmetry. However, data openness has also been proven to go hand in hand with trust control. The latter has been found to be the condition that needs to be met so that risk from data openness is mitigated, while information asymmetry is the ultimate scope.

4.1.8.1 Trust and control

Interviewees have been referred to the need of trust between interacting actors but have further underlined the risk involved in interactions and the need for control. Data openness and transparency is expected to increase the confidence of trustees. The parameter of risk in DLT transactions has been raised by interviewees, especially in highly dynamic environments. Trusted intermediaries can be removed only if the risk factor will be adequately addressed by their replacement. Because interactions by default involve some degree of trust (Lewicki, Tomlinson and Gillespie, 2006) informants underlined the need of control. Data openness, visibility and transparency will facilitate control over possible deviations and allow control over manufacturing partners compliance with prescribed standards.

"We need to control those transactions with our partners, that our in-between system integration has not managed to deal effectively with supply chain information coordination."

"Transactions with unfamiliar partners carries risk that we need to control."

The fact that a supply chain actor possesses more, better or complete information about an element, does not only raise barriers for efficient supply chain synchronization. On the top of that it might lead to opportunistic behavior. Interviewees mentioned that control over those actors and processes that are sources information asymmetry should be the focus of a new solution that promises trust and disintermediation. Informant answers revealed that, when manufacturers have the power to achieve visibility into their partners' supply chain operations and the respective data without opening more data than usually by following a need-to-know approach, they will act accordingly. Let alone if they are in position to take advantage of their ecosystem position and exercise, if needed, their influential power.

4.1.9 Exercise of influence

All interviewees converged to the conclusion that achieving high level of trust with their supply chain partners does not conceal the danger to become more tolerant to any kind of deviations due to their relationship established.

4.1.9.1 Trust and control

According to our data, inbound and outbound partner dependency, role and ecosystem position will not affect manufacturer's control mechanism irrespective of the trust level achieved among the interacting entities. Based on interviewees' answers, key and non-key supply chain partners, irrespective of their dominant or niche ecosystem position (Moore, 1993), seem not to have the power to bend the prescribed metrics by the manufacturer, even if they are highly trusted by the latter. Exercise of influence on behalf of the partner, based on actor's ecosystem position or his key role in the manufacturer's supply chain, flourishes when transactions lie in transparency grey zones and that in turn, triggers ambiguity on identified supply chain deviations.

"High level of trust will facilitate our control over our supply chain partners but this does not mean that we will lie into a trusted relationship and become more tolerant to deviations."

Data openness impact, under the context the network effect created, due to the expansion of the respective ecosystem, has been discussed with the interviewees and revealed a benefit vs risk dilemma. Balance on that dilemma seems to be a central decision-making notion for the interviewees dilemma to open more data than usual in order to attract more partners. Our data revealed that manufactures will exercise their influential power, if they can, to avoid opening their internal data but ask for their partners to open theirs. However, the same case though inverted, might apply when actors, that they wish to collaborate with, have the advantage of expertness or their dominant role in the supply chain network to negotiate from a position of strength. The bottom line is that power dynamics play a significant role in ecosystem expansion through data openness and what seems to weigh more is the benefit vs risk calculation. The risk stems from the privacy concerns of opening more data or from not doing so and miss important partnership opportunities.

"Our partners know that opening more data allow us higher visibility and control, among other, and this is not always an incentive for them to do so, unless we make it mandatory for our collaboration."

"If opening more data than usual is necessary to attract the partners that we wish to work with, then we can think about it but we will need a mechanism to meet our data leakage and data privacy concerns"

Although ecosystem expansion through data openness does not seem to be of a significant concern for manufacturers, their propensity to data openness with their 1st tier material suppliers and LSPs is evident. Value creation and value proposition seem to weigh more in manufacturers' decision to reform their data management and data share practices but only to the extent they maintain some control over the process and the relationship with their partners. Expanding those practices to ecosystem actors that lie 'beyond arms reach' has been identified to be applicable only for customers and not for any other ecosystem actors. Based on our data power dynamics seem to favor customers, that are in position to affect manufacturers data openness decision, for the sake of even temporarily gaining higher visibility into areas that affect manufacturers value proposition attributes of their interest.

"Would dare to say that if our customers require more visibility and transparency then we, then we will demonstrate little resistance into opening more data than usual."

"We will work together with our 1st tier suppliers to share more data, if necessary, to improve our supply chain operations but going beyond that level, to partners that we cannot control directly is a nice to have case. However, I really doubt whether we will consume any resources into that direction."

4.1.9.2 Need to know basis.

The role and position of manufacturer's partners seems to play significant role in its decision to data openness. When data need to be shared among two dominant players, the expected benefits do not seem to completely lift the concerns that are related to partner's data management capabilities. It is another indication that manufacturers hesitate to open their data to partners that, at least to a large extent, cannot control or even govern the relationship with them.

"In the case that we cannot actually control the relationship with our partners we cannot actually control how they will manage our data."

Manufacturers in regulated industries seem to be hesitant to open more data than those shared with regulatory bodies. The control over the relationship with their partners and the commitment created when data are opened to regulatory bodies, make manufacturers skeptical to share more with any other partner. Consequently, the rules of data exchange are to a large extent framed by the rules that the regulatory authorities impose.

"We already open our data to authorities and some of those data could also be opened to our partners."

"We need to be really careful what data we share with our partners, since we also share specific data with authorities."

Some interviewees stated that bringing visibility for all partners at the same level, that would not go beyond the data opened to authorities, would be highly desired to the extent that data openness would facilitate the proof of supply chain conformity to regulations. Those manufacturers stated that they would clearly push their partners towards this direction.

"Since we need to prove our supply chain conformity to regulations and standards set by authorities, would be resource saving to achieve visibility through data openness with all our partners."

4.1.10 Business expansion.

Business expansion has been found to be the lucrative resistant strategic intent that raises data privacy and risk concerns. To the extent that DLT adoption at supply chain level is viewed as the mean or incentive for business expansion, then manufacturers are keen to support DLT adoption, even by taking higher risks than usual.

4.1.10.1 Data openness based on congruence between benefit and risk.

Apart from streamlining their supply chain operations and improving their performance, one of the most highlighted factors that, based on our data, lifts most of data privacy concerns is business expansion. In the case that partner base expansion, by incentivizing more actors to join a network of high data visibility and transparency through trusted data exchange, scopes to new market entry and exploration of new business and market opportunities, then data openness concerns seem to bend. This specific characteristic revealed by interviewees is not directly related with the trust, as relationship factor, among interacting parties. It lies more into the need for reliable trusted information, which is necessary for manufacturers to deal with the risks and the ambiguity related to business expansion. It is yet another indication that for strategic decisions, such as those related to value proposition configuration, manufacturers are keen to take more controlled risks. For any such decisions related to open more data than usual, organizations weigh the congruence between benefit and risk.

"Accessing new markets or exploring new market opportunities involves taking risks and data openness in a transparent and trusted way is a risk that we consider."

"Accessing trusted information when it is about expanding our business, whether it is about market data or how to access new markets or introduce our products, is priceless "

"We would open more data to attract more partners for specific reasons such as those related to new products launch and in particular into new markets."

4.1.11 Data openness as barrier to ecosystem expansion

Manufacturers seem to demonstrate higher propensity to open their data to their 1st level supply chain partners but are skeptical, in general, to act respectively to interacting actors beyond their expanded business network at ecosystem level, unless specific measurable proofs exist.

4.1.11.1 Need-to-know basis.

Data privacy concerns demotivate manufacturers to be involved in a network with actors that cannot control data share. Most interviewees, as expected, mentioned that their attitude is to share and open only whatever data are necessary at the time that this need emerges, unless specific circumstances come up. Business expansion and data openness to 1st tier suppliers that manufacturers can control is the main conclusion derived from our data. At that point it is worth mentioning that due to the specific characteristics of DLT, the ecosystem that emerges when DLT is adopted needs to be constantly expanded so that the network effects created guarantee the sustainability and the security of the ecosystem (Pilkington. 2016). Based on that axiom it seems that the manufacturers need to weigh the expected benefits to take the risk and move beyond the 'need-to-know' basis as their data openness attitude. Motives such as value proposition configuration and added value on supply chain efficiency has been proven to list some of the data openness concerns but what seems to be needed are measurable proofs that data openness, ecosystem expansion and expected benefits far outweigh the risks.

"We need solid reasons to share our assets (meaning the data) with unknown to us entities. In any case we share whatever is necessary when any such need emerges"

4.1.12 Relationships with high risk

DLT is viewed as the mean to allow flexibility in the case of relationships with high risk. DLT architecture that would support combination of data kept on and off the network is viewed as the vehicle to drive relationship re-establishment and allow flexibility under the terms of gradual data openness when risk concerns arise. At the beginning of a relationship manufactures view DLT as the mean that will allow them to elaborate on other trusted actors' data and asses the expected risks in their decision to proceed with partnerships with other, unknown to them, supply chain actors.

4.1.12.1 Partner dependency criteria for data leakage prevention

Interviewees seem to hesitate to view data openness as the mean to create more trust and improve their supply chain operations, when their 1st tier material supplier is cooperating with any of their competitors. In most cases, as mentioned by informants, it is inevitable not to establish partnerships with material suppliers that are also working with competitors. However, the power of influence and the dependency, that the manufacturer has over its material supplier will determine any data openness decisions. Apart from 1st tier material suppliers, for any other ecosystem actor, inbound or outbound supply chain partner, data openness does not seem to be affected by the partner's established relationships with manufacturer's competitors.

"We do not pay that much attention whether our partner is cooperating with any of our competitors, unless it is about our key material suppliers."

"Data openness is a way to build trustworthiness with our material suppliers and facilitates any supply chain improvement effort. However, when they are collaborating with any of our competitors, we need to be very cautious on what data we open and when."

4.1.12.2 Trust threshold to re-establish supply chain partner relationships.

Data openness and visibility have been revealed to be key prerequisites when manufacturers try to re-establish broken relationships with their supply chain partners and other ecosystem actors. Those relationships involve, by default, high risk, since they have already been disrupted once. Interviewees mentioned that to prevent it from happening again, higher trust thresholds need to be considered and data openness, visibility and transparency between interacting parties with little or no trust does not only facilitate that effort but is a prerequisite. In addition to information sourced by social network information transparency needs to be established through data proven evidence. This has been proven to be a prerequisite set by manufacturers not only at the beginning of the new era of the relationship, but its status needs to be monitored closer and for longer time than usual. High risk relationships has been proven, based on our data, to need more effort to be fixed irrespective of the actor's dependency, ecosystem position and influential power.

"We need trusted evidence that we can re-establish effective partnership with a vendor and we also need to monitor it closely than usually"

"Irrespective of the reason of a broken relationship and the role of the partner to make it work again, we need to establish much more trust than we initially did. This time we need to make sure that mutual expectations will be met and it is important to realize beforehand that both parties are motivated towards it."

4.1.12.3 Social network source of trust

When partnerships, even temporary, need to be established among competitors, some form of trust is being built based on predictability. The latter is the trust variable that underlines the ability of one party to forecast another party's behavior. Predictability, under the context of a trust variable, has been mentioned by interviewees to mainly rely on social network (Doney and Cannon, J1997). If a social network exists, the unknown agents are connected through a series of intermediate agents that allow computation of trust evaluations based on recommendations and reputation. Elaborating on the social network dimension of the information source, one partner can make cognitive predictions as long as there are trusted intermediaries that are willing to share that information. Transparency and trust established among interacting parties allow actors to be more open into sharing information about 3rd parties.

"In an interconnected supply chain environment, it is not that difficult to get some feedback for a partner candidate through your extant partners, as long as they are trusted and are open to share that information"

Data openness might be a strong incentive for 3rd parties to collaborate with the manufacturer, but privacy and data management are concerns that affect manufacturer's data openness decision making. Apart from the technicalities of the mechanism, which will ensure data leakage protection, data openness decisions are related with the intentions and the integrity of the interacting parties. For unknown to each other actors a useful source of information can be provided by trust sources within a social network. Decisions based on stereotypes, recommendations, as well as system neighborhood and system reputations allow interacting parties to predict the behavior intentions of their perspective future partner (Sabater and Sierra, 2002). This intention-based trust that relies into social network references has been mentioned by interviewers to affect their decision to open their data to future partners. On the top of that, it also affects manufacturer's propensity to open more data than usual to incentivize specific ecosystem actors to collaborate with them. Our data also revealed that social network as source of trust plays a significant role in collaboration characteristics irrespective of the role, the dependency and position that actors hold in ecosystem.

"Beyond system technicalities specifications it is important to assess candidate partner's integrity and intentions before we share more data than usual. The candidate partner is also expected to be the same open as we are to share his data."

4.1.12.4 Data openness based on congruence between benefit and risk.

Manufacturers' decision to open more data than usual to unknown ecosystem actors includes benefit-cost calculations. Even in partnerships that are of high risk, since no established relationship exists or not highly trusted information from social network can be easily identified, calculations that are based on benefit vs cost balance, bear the weight of the decision-making process. Interviewees seem to converge into the fact that even in that kind of relationships if the expected benefit is much higher than the cost, such as the cost of a lost opportunity, then they are keen to open their data but for a test period only. It seems that under these circumstances, manufacturers identify the strong expected benefit of transparency and visibility promised by data openness but wish to take a control risk.

"In a situation with high risk we can start with the vendor onboarding phase and for a 'test' period gradually share more data than usual. After that we will re-evaluate the results and proceed respectively"

Another finding that emerged from our data is that improvement of value creation and value proposition seem to weigh significantly into manufacturers' decision to open a substantial amount of data to external entities. Customers and 1st tier supply chain partners seem to be prioritized in this endeavor. However, a new finding is that there are concerns about how much can manufacturer's partners build on data opened. Meaning how much they can enhance their capabilities through new knowledge created to the extent that manufacturer's negotiation position will be diminished.

"By opening our data we share part of our know-how and that might be proved to be a drawback for is in future negotiations. We want to work together with capable and competent partners but what if we end becoming too dependent on some partners.

4.2 Single-case study research findings regarding mRQ2

In this section, we describe our findings that emerged from the data in relation to the five (5) overarching themes we inductively identified as presented in Figure 8. These themes put the notion of trust in the center of DLT adoption causation at in-house supply chain level.

4.2.1 Single source of truth

The first theme identified was the need for single source of truth that would eradicate the inefficiencies occurred when multiple sources of data need to be combined. Even in a supply chain with high level of information system integration, information from multiple sources need to be synthesized, analyzed and be converged to conclusions that should ideally raise no arguments. Irrespective of the easiness of data access, since they are kept into trusted in-house information system solutions e.g., ERP, and the level of data contractions, the loads of data may trigger inefficiencies in respect to data source combination.

4.2.1.1 Aggregation of different sources of evidence

Interviewees underlined that for daily operations there is quite high level of information mining automation through rigid, predefined standard reports and standardized data flow exchange. However, the main mechanism that validates the efficiency of all processes across all departments is the multiple periodical audit system that runs all in in-house supply chain levels. It has been referred by all interviewees as the mechanism that brings to surface in-house supply chain inefficiencies and is the main information source for their evaluation that will further indicate the appropriate preventive actions.

"We audit everything thoroughly and periodically, from sitting next to each workstation at the assembly line all the way to evaluating supply chain performance at mid and senior managerial level."

Effective combination of internal and external audits at all supply chain processes such as production, system, 5S, lean practice efficiency, quality audits, supply chain risk assessment etc. is performed in a steady cycle, that varies according to the audit type from one week to two years. The audit process engages all supply chain departments at all levels and provides an in-depth insight of all supply chain procedures. This vital process however has been mentioned by most of the interviewees to be quite exhaustive and resource consuming, in terms of preparation and execution. Audit simulations and some data analysis rework is often requested to crosscheck findings. Auditors have access to the requested information system even prior to the execution of audits for their own preparation purposes. Data are analyzed and presented to all stakeholders before, during and after the audit. At the end of the process a consensus on the findings and the actions that will come up has to be reached. Based on such a well-structured process, which relies on high data visibility the findings would expect to raise little or no debate, since data speak for itself. However, it has been found that thus is not the case.

"We record almost everything and we know that we do not have false or contradicted information in our systems but interpreting them is another thing"

''The truth is in our data and we know that we have loads of them but sometimes it is hard to come to a consensus when we argue on findings based in them"

Aggregating different sources of evidence leaves ground for miscalculations, misinterpretations, and different evaluation of the findings. A finding raised by the interviewees, that is based on different sources of evidence aggregation gaps, is the way that external contractors' contracts that operate in house are executed. In the case of a pay-per-use equipment or a fixed term contract executed in-house by external entities the contract follow-up and implementation from specification conformity to payment processes is monitored based only on company's data. Standardized, predefined data gathering processes are in place but only with data collected by the company's own resources. Crosscheck with service provider data is seldom requested and although arguments do not happen often, when they emerge, the reason is that company's collected data deviate from the data collected by the contract service provider. The interdependence between the manufacturer and the service provider, the position of each company in its respective business ecosystem and their power imbalance, leaves space for various argument settlements.

"It does not happen often to have deviations in our data compared to those held by out contractors but when it does, we work on it on a case-by-case basis"

4.2.2 Data-driven decisions.

We identified the need for data driven decisions as the second main theme. The main difference between that theme and the previous one, meaning the single source of evidence, is that the latter leads to the former. Trusted data that stem from the existence of single source of truth, affect the factors that influence data driven decisions at in-house supply chain context. Investment reasoning, that targets into putting in place corrective and preventive actions to diminish production related deviations, root causing of Service Level Agreement (SLAs) variances and elimination of productivity KPIs ambiguity, are the second order concepts which fabricate the data driven decisions.

4.2.2.1 Ambiguity on productivity KPI evaluation at ecosystem level

All interviewees engaged in the production system indicated that, on daily basis, productivity and quality are the outmost important concerns. Although operations managers receive daily production reports for those issues, in the form of key performance indicators (KPIs) and other descriptive reports, it has been observed that there might be factors which affect productivity that are neither recorded nor included in those reports. That allows the creation of a grey zone when productivity KPIs are analyzed and the root cause effects of productivity performance deviations are investigated and discussed. Productivity metrics are more composite compared to other metrics, such quality metrics, in the sense that more factors that just production output numbers need to be considered for their calculations. Tracking and measuring production system efficiency drives performance improvement decisions. High level of data record does not necessarily guarantee the accuracy of the calculations of those metrics. Tasks can go unfinished for a bunch of reasons that might haven't been recorded and the respective KPIs can mislead the decision makers. In that case more effort is required by the decision makers to spot and verify the reasons of productivity deviations as reflected by the calculated metrics.

"*Sometimes in our daily meetings we have to keep notes on incidents referred by production supervisors that might affect productivity KPIs, and you need some experience to guess which incident might affect.*"

4.2.2.2 Investment reasoning

Although many well-structured audits are in pace, no matter how efficient they might be, their periodical nature leaves space for inefficiencies that are not brought into surface. Audits focus on data and processes but with a sampling logic. Investment decisions are taken on specific time over the year but as all respondents mentioned, periodical investments occur mid-season, if necessary, since there is always budget available for specific reasons. Apart from investments that are by default required in the case of new product designs, new production specifications and any other supply chain capability and capacity upgrade that is designed as part of a strategic plan, there are investments driven by supply chain evaluation and audit results.

"It is not actually often to encounter problems that have not been spotted in audits or in daily operations and have been overlooked, even those that their solution requires some low budget. In some case though we discovered that minor repeated problems solved on the spot concealed larger problems that came to surface later"

Respondents mentioned that in some cases in-house supply deviations inefficiencies that are corrected on the spot, meaning relative quickly, are not revealed in audits. Those inefficiencies sometimes conceal larger malfunctions that might come up in the future to the same or larger scale. Any such decisions usually come at higher cost since they embed the risk of a fire-fighting solutions Hence, apart from the cost aspect, there is some risk when they are not brought into surface and analyzed through a well-structured process, e.g., audit, that involves many stakeholders.

4.2.2.3 SLA deviations

One source of SLA deviation has been observed to be the visibility into vendors' data and the decisions that must be taken based on that. Although this case falls mainly under the information asymmetry theme, that is presented in the next paragraph, we will refer it here recognizing the direct relation between SLA deviations and data driven decisions. Data exchange between the company and its vendors, as well as visibility on 1^{st} and 2^{nd} tier suppliers assist all parties to enjoy an on-time, at the right place and a right product delivery. Focusing on the first the informants mentioned, as expected, that timely inbound receipt of supplies is critical for in-house supply chain operations and in particularly for production system operations. They also mentioned that most supple chain inefficiencies have been spotted around that part of the supply chain. What is of particular interest here is that the company recognizes the possibility of time deviation regarding supply deliveries, takes efforts to work with the vendors to improve that but also recognizes that although some deviations will still occur there are may be valid reasons to keep cooperating with those vendors.

"We work close with our vendors to improve SLAs but for some vendors we almost know what deviations to expect and act proactively to stock on time what we need, even though we sometimes get unpleasant surprises."

"More production process information exchange integration with our vendors, could save as some pain."

Real time visibility on vendor's data would give manufacturers the flexibility to take overstocking or "stock earlier" decisions as a proactive action to reduce risk. Inventory means cost. Investing in supplies and tying capital under the form of supplies as a proactive measure to avoid vendors SLA deviations, are data driven decisions triggered by the capability to forecast those deviations. Access to trusted vendors' data increases trust among interacting parties and leads to data driven decisions that mitigate supply chain risks.

4.2.3 Information asymmetry

We identified information asymmetry as the third and the most highly influential theme in the need for in-house supply chain DLT adoption. The fact that either some departments internal to the company or the vendors possess more, better, imprecise or incomplete information about an element leads to supply chain deviations and risks. Information system integration plays a significant role in information access and diffusion. In addition to that, efficient supply chains are majorly based in high end information systems and demonstrate high integration with external and internal entities. However, 'near real time' data visibility and elimination of visibility silos is still a prerequisite. The questions "What is the minimal data to open?", "What flexibility do we lose vs what are the expected benefits when opening our data?" are stemmed by the perception that "data are our assets". Those concerns were raised by the informants and even though they operate a highly efficient supply chain, which adopts best practices and high-end processes, those concerns especially at higher managerial level, were evident. The more the researchers dived in the lower levels of managerial hierarchy the more cleared it became the need for actions and solutions that would reduce information asymmetry. We aggregated the aspects of information asymmetry into the SLA deviations, production disruption vulnerability, PPC revisions and intra-group entities visibility silos.

4.2.3.1 PPC reviews

Although the manufacturer demonstrates high level of trust in its upstream supply chain vendor's data, the lack or the limited visibility into its 1st tier supplier data has a dual impact on the PPC revisions. PPC revisions are caused when materials are not delivered on time. Another case is that when for any reason the manufacturer needs to perform a PPC review within a short notice, he lacks all the information that would indicate the approval or rejection of the proposed review. Manufacturer's supply chain demonstrates high efficiency, in terms of quality issues in material received by vendors, so the PPC revisions concerns lie mainly in the factor of delivery time.

"We need to quickly run PPC review scenarios before we approve any and to do so we need a lot of trusted information that is not only held internal to the company but involves capacity, inventory, deliveries etc. of our vendors "

"Delays in material receipt is among the most common reasons to review our production plan."

The fact that there is not extended visibility in the whole inbound process, e.g., vendors dispatch information, 3PL handling, transportation etc. does not allow the company, no matter how much they trust the information provided by their material vendors, to assess the feasibility of a PPC review scenario. The manufacturer cannot have a trustworthy close follow up when the PPC review plan requires tight time windows until material receipt. On the top of that late material deliveries could cause production planning disruption. Although the informants underlined that there is close monitoring on inbound deliveries and that they perform highly efficient material, inventory and MRP activities to prevent PPC disruptions, PPC reviews due to delays can well be the case.

4.2.3.2 Production disruption vulnerability

We observed that although PPC reviews are happening with some frequency, production disruptions had been a rare but not obsolete case. Some interviewees mentioned that there had been cases that were close to cause production disruptions due to late arrival of critical materials. For critical materials there is close follow up on deliveries, while stock levels and time windows have been set up and monitored quite efficiently assisted by lean, e.g., VMI and Kanban, inventory management practices. However, limited information system integration between the company and the involved inbound supply chain partners as well as the restricted visibility into vendor's data, prevent the manufacturer to reduce even further production disruption risks.

"It has happened to find out that based on system dates due to unexpected delays we would be out of stock for specific critical materials and had to take "red alert" actions escalating rapidly the diagnosed problem to higher managerial level, so that we take approvals for "for- fighting" actions to prevent production disruptions."

Noncritical material inventory is treated and managed, in a different way and no informants mentioned neither did the interviewers observed cases where non-critical materials leaded to close-to production disruption cases. It is also worth mentioning that quality departments had not been observed to be overshoot with quality deviations of incoming material to the degree that would justify any production disruption.

4.2.3.3 SLA deviations

Lack of near-real time visibility on vendors' data, such as inventory level, material availability, production capacity attributes and service delivery availability, causes deviations that depend on delays in material or service delivery. Frequent data exchange and limited information system integration with vendors which procure critical material for the manufacturers, mitigates the risk of SLA deviations but does not eradicate it. The opinions of all informants converged in the fact that material delays are the main reason for SLA deviations. Interviewers observed that the manufacturer has taken actions to share data, in some cases in real-time, only with selected vendors that procure critical materials. In some other cases periodical, although frequent manual data exchange practices are in place to facilitate planning and inventory management between the organization and selected critical material suppliers. For non-critical material suppliers though limited data exchange practices are in place. Data openness has been observed to include data sharing, only on behalf of the manufacturer and not through a bidirectional logic.

"Selected suppliers have real time access to our data but in most cases, we follow up closely all our orders."

"Most of our logistic service providers have the capability to provide end-to-end visibility in their systems."

"We expect delays because something went wrong and we take that into account into our planning but we also want to stay in line with our leanness philosophy and absorbing delivery fluctuations cannot always be acceptable"

The same applies for service providers that are involved in the inbound delivery chain. Most of the material procured are under the ex-works incoterm, meaning that all the way from seller premises to the company's receipt point, the company bears the full responsibility in the material procured. Service providers, such as 3PL, forwarders, last mile delivery etc. do not actually provide un-interrupted end-to-end data but it depends on the service providers' capabilities to release any such fragmented data.

"As soon as the suppliers are onboarded and we believe that we put a lot of effort to support them on that, the quality control through its regular procedures takes over the weight of inspections and extra data are requested if our quality reports and the respective KPIs indicate that something goes wrong."

Another worth mentioning practice is that the organization, as expected, emphasizes on the supplier onboarding phase, especially for suppliers that provide subassemblies or perform some external manufacturing. Suppliers' or external manufacturers' SLAs mainly focus on the time aspect of the delivery because that is the main cause of SLA deviations. Collaboration between company departments, visits on vendor's premises and other activities contribute to the smooth vendor onboarding phase. Conformity with specifications and particularly low level of incoming material rejections due to quality deviations are the main concerns. As soon as the supplier is successfully on-boarded, there is not any visibility on vendor's manufacturing procedures and practices and manufacturer's Quality Control (QC) department becomes the first control point on the material received. High level of trust on the carefully selected material suppliers has been confessed, QC department is not overshoot and long-term relationships are established, at least with the critical material providers. However, in the case of severe quality deviations significant inspection effort and time-consuming procedures are required. In that case bilateral access to trusted data would reduce the effort and the consequences caused by a long-lasting resource consuming evaluation procedure.

4.2.4 Cross functional collaboration

The conditions under which internal departments collaborate and people with different functional expertise must contribute into preventing in-house supply chain disruptions has been identified as the third main theme. We present our data in conjunction with the second order themes of external communication inefficiencies, Information flow bottlenecks and production disruption vulnerability.

4.2.4.1 External communication inefficiencies

Although high information system integration at plant level is in place, that is not always the case between the factories and the entities in general that belong to the same group of companies. Apart from the group headquarters that have visibility on specific parts of information at plant level, this is usually not the case for each production plant. Although production plants are usually dedicated into the manufacturing of different products, they need to collaborate with each other. Collaboration between plants at operational level facilitates communication. When for instance one party holds information, usually technical, on specific attributes that apply to production or design issues and based on that needs to ask for further assistance or addresses a specific request to another intra-group factory. High supply chain efficient organizations push towards information system integrations at group level, to facilitate knowledge exchange, e.g., same teams such as R&D design teams share the same design database, since allowing more experts to access the same data facilitates collaboration.

"We get technical requests on specific equipment specifications by other intra-group plants and sometimes although that we speak the same 'language' there is some misunderstanding, since not all respective data are clear and shared, although they are in the same database."

Similar effects rise when communication between in-house supply chain departments and vendors must be performed indirectly through other intra-company departments, e.g., procurement. Information distortion, delays, unnecessary follow ups, approvals to share data are root causes of communication inefficiencies, when entities with different background are the gatekeepers of the communication. Apart from the obvious effect of delay and an unnecessary chain of information exchange that must follow rigid and controlled communication rules, trusted and fast exchange of information without intermediaries would streamline would increase communication accuracy and add more value to the respective processes by removing waste, such as delay and unnecessary information exchange steps.

"We follow rigid standard procedures when we need to communicate with external vendors. This sometimes makes the communication more difficult than it should be. Especially for technical issues we end up sharing data with our partners because we need to do so but interventions of intermediaries in that process often makes it harder than it is."

4.2.4.2 Information flow bottleneck

The importance of capturing customer feedback, evaluate it and extract conclusions is obvious for every organization. Efficient supply chains make sure that this feedback is captured and evaluated properly and timely, so that if any problem-solving actions are required, those can be put in action in the shortest time possible. We observed that a well-structured mechanism to capture customer feedback is in place, as expected. Interviewees agreed that if any kind of problem-solving actions is required at any stage of the supply chain, then that project will get high priority. What is worth mentioning though, is how the customer feedback is diffused and communicated internally.

"Usually, customer feedback is directed to QC departments, if it is about technical issues and after their analysis further actions are decided, either by the Q.C. department itself or by higher management level based on the report derived. All these deviations, if they are proved to be such, are discussed in periodical meetings held for that purpose only."

The standard procedure defines a clear serial information flow path, where initially one department, e.g., Q.C. if it is about technical issues, provides the initial customer feedback evaluation analysis and directs who will be involved after that. Although periodical meetings with many stakeholders are held and KPIs monitor any deviations identified via customer feedback, there is a clear information flow gap that lies in early data availability to the right people. The sequential information flow process contains the risk that some value of customer feedback might be lost if the departments that decide who will be involved in the process do not capture it. The safety net to capture any such failure during the respective debriefing meeting is of some value but whatever additional actions might come up afterwards will be at whatever cost this delay might bring. In the case that external supply chain partners are involved in the deviation or incident reported, those partners are pushed to provide feedback in very short time. Data availability is achieved in short time, but the challenge is who is involved in the analysis to follow and when. The organization needs to be confident that final reports do not miss anything and are concluded as fast as possible and the reported sequential order of information flow has a bottleneck yet at the very beginning of the process.

4.2.4.3 Production disruption vulnerability

Well-equipped and well-organized in-house maintenance department takes over all 1st level asset maintenance works, where applicable. 2nd level and pre-scheduled periodical maintenance on specific assets are delivered by external entities. However, some informants mentioned inefficiencies in the coordination between production and maintenance departments that are caused due to material and knowledge exchange bottlenecks in the machine shop. Delays in identification of equipment problems, problem investigations and troubleshooting have been mentioned to be cases of production disruption. Data synchronization for all involved departments has been observed that would allow a better balance between maintenance works and production planning and would consequently reduce the risk of production disruption. This conclusion is also applicable in the case that although some sophisticated modern equipment would allow real-time remote asset operational data access from externa maintenance providers, this is not the case. Access is allowed only in the case that cause-effect analysis performed initially by the manufacturer indicates it but that comes after the maintenance procedures have been initiated.

"It is rare to be honest to face production disruptions due to maintenance issues however in some cases it has been proven that we were lucky that we didn't experience a disruption and that has been discovered latter on after the maintenance reports. We have built up a high-end maintenance know how. Our maintenance service suppliers do have it as well, though and a better combination of both would further reduce our risks."

Production disruption vulnerabilities due to material stock-out caused by late deliveries have been observed to be extremely rare. Interviewees agreed that their information systems allow them to plan inbound material flow and stock replenishment efficiently. The respective KPIs and inventory reports confirm that. However, some interviewees involved in production system, mentioned that when a delay is identified the departments that are in contact with the suppliers put their maximum effort to bring it back to normal. Despite the efforts, sometimes, the lack of real-time information and the lack of visibility and transparency on vendor's data might mislead the manufacturer, resulting in late communication of the expected deviation. Data communication and trusted information diffusion to all involved parties would add another safety checkpoint to prevent or even reduce the risk of production disruptions.

"We know that there are things that can go wrong in material delivery no matter what effort s you take to prevent it from happening. From our end we plan and monitor that process with strict processes but sometimes we focus that much into trying to solve the problem at department level we do not involve early enough all stakeholders"

Well-structured internal procedures enhance the control over the processes at both financial and operational level. For instance, ordering processes, all the way from technical approvals to financial approvals, document matching, receipt, quality control and payments is mandatory to be very well designed and structured for an efficient and effective supply chain operation. Control though, should not outbid against transaction speed and timely execution of all interrelated processes. Late execution of transactions, e.g., document matching, due to several steps or long approvals increase the risk of delays, e.g., in maintenance related material or service orders, that might cause production disruptions.

"It is not really rare to keep an eye on our follow ups with other departments to make sure that no delays will emerge."

"R&D related changes need approval from headquarters and that can take more time than expected."

The fact that the company operates through a highly integrated information system and all critical supply chain operations and performed through that system, allows for timely information exchange between production planning and production system stakeholders. Consequently, the supply chain phenomenon of coordination inefficiencies between planning and production system departments, since the former act as data feeder to the latter, has not been referred by informants neither has been observed by the interviewers.

"We all have some stand-alone spreadsheets that supplement our work and there are cases that the use of these data is even more critical compared to the data kept in the central information system."

However, some spreadsheets have been developed as supplements to the information kept in ERP. Some interviewees mentioned that there had been cases, although not highly periodical, that information kept in separate databases and not in ERP had been misused, e.g., data in hidden folders had been overlooked, and incomplete planning and material break down related data were passed internally to production departments. The lack of an automated check point that would prevent the execution of a transaction if incomplete information was identified, irrespective of who has the authority to approve and execute the transaction, would increase cross functional collaborations effectiveness.

4.2.5 Competition

Competition contexts characterizes not only the mistrust on the real intentions between the interacting parties but also fuels the imbalance between trustworthiness and decision flexibility when it comes to data openness dilemmas. This overarching theme is further analyzed through its second order themes, being PPC reviews and conflict of interests.

4.2.5.1 PPC reviews

Lack of inbound material end-to-end visibility can lead, as mentioned earlier, into PPC reviews. This is a conclusion drawn by all informants but what is of particular interest is the reason behind it. Information asymmetry has been mentioned as an overarching theme under the condition that trustworthy information is exchanged between involved parties. In some cases, external material suppliers are incentivized to favor one customer over the other, when they feel they are in position to serve both as promised. Another case is that of a missed SLA on behalf of one of the entities involved in the material delivery chain. The deviation can be easily spotted but may be too time consuming to identify what went wrong when many entities are involved in the delivery chain. Total SLA violations will always occur to some extent, but although usually case the manufacturer can absorb the consequences, when an unexpected for any other reason PPC review needs to be applies any such SLA violations might become a showstopper for the review designed.

"It has happened, that some of our vendors did not serve us in favor of another customer. It is not easy of course to identify any such intentions because our partners know that we have low tolerance on that behavior, unless something really unexpected happened but still. We are not actually happy to review our production plan due to any such behavior but hopefully it is something that does not happen often."

4.2.5.2 Conflict of interests

The situation described earlier that one vendor may favor one customer over the other, apart from the obvious impact on PPC reviews demonstrates a clear conflict of interest between the interacting parties. Although large organizations have the power not to allow it to happen or at least prevent it as much as possible, the possibility of that phenomenon to appear occasionally is still there. All informants clearly recognized that trustworthiness in transactions, visibility and transparency in information exchanges are the keys to restrain any such incentives. Knowledge exchange between entities that belong to the same group of companies in highly desired, as mentioned by all interviewees. To make it happen does not necessarily need high end information system integration and high level of data openness, since it can be achieved through other technics and methods, such as workshops and seminars as discussed by informants. However, collaboration at operational level needs to overcome data visibility silos in a transparent and trustworthy way. For instance, collaboration based on raw material, equipment spare part availability and lead time delivery are factors that should be facilitated through information exchanges between production units or any other entities that belong in the same group of company. Decisions not to act accordingly need a solid reasoning and leave space for decision motive ambiguity.

"When we are in rush for equipment spare parts, if we can get them faster from another intra-group factory that has availability in and does not need it rather than from the vendor, we prefer the former instead of procure it from our vendor."

In a large organization there is undoubtedly competition between the production plants. The most efficient and most productive plants gain more attention to the higher management, will potentially attract more investments and consequently will be assigned with more contracts. High level management in group of companies take actions to prevent this informal completion from impacting knowledge transfer and overshadow the benefits of collaboration. Data openness and trusted decisions based on that are of a major importance to this effort.

4.3 Single-case study research findings for subRQ2.1

In this section, we describe our findings that emerged from subRQ2.1 data analysis. As presented in Table 7 the 1st order concepts that are impacted by DLT adoption at in-house supply chain level are segmented in two categories. Those that are impacted only in the case of an unexpected event such as e.g., lean improvements, product change requests, unexpected material flow disruptions that could cause any kind of material production flow change and those that DLT adoption affects production processes under normal conditions. As explained in 3.3.4 section in our research, due to case study finding generalization scope, we will consider only the second case. As in presented in Table 7 the mRQ2 1st order concepts of 'Lack of visibility on any of asset maintenance service providers data', 'Inefficiencies in coordination with internal asset maintenance & machine shop departments', 'Inefficiencies in internal (intra-group) communication on technical subjects (intra group visibility silos)', 'Visibility of intra-group entities (factories) data' are related to DLT impact on OEE. Total Preventive Maintenance (TPM) goals is to enhance equipment efficiency and this goal is measured by using Overall Equipment Effectiveness (OEE) (Suryaprakash, M. et. al. 2021). It is therefore obvious that all asset maintenance and equipment uptime related improvements that have been identifies by 1st order concepts and lay the ground for DLT in-house supply chain adoption are related to OEE. OEE is based on the aspects of availability, performance efficiency and quality (Lesshammar, 1999). The first is related to equipment failure and set up adjustment losses, the second aspect is related to reduced speed and minor stoppage losses and the third sector is related to rework and start-up losses (Singh, Khamba, and Singh, 2021). Based on informants' feedback DLT is expected to improve visibility to near real time trusted information held by other processes, such as equipment planned maintenance, equipment breakdown forecast and preventive maintenance planning, PPC reviews, and inventories held end to end within the production processes. These factors allow production and maintenance planners to adjust equipment uptime in a way that will increase OEE.

Data revealed that six (6) out of thirty-seven (37) production processes that are involved in HA-OEM production flow had been found to be affected by DLT adoption. The processes are marked Apdx Figure 7. The reasons behind the small number of processes affected is that HA-OEM demonstrated OEE over 85%, which is the Japanese Institute Maintenance standard (Nakajima, 1988), in all production processes and the TPM plan that is operated by HA-OEM. That KPI indicates that HA-OEM employs a highly efficient TPM plan that results in high OEE which doesn't leave that much space for improvement. This is another indicator that HA-OEM case is ideal for studying DLT adoption at in-house supply chain, since one of the case study selection criteria had been high supple chain efficiency that leaves no profound reason for DLT adoption.

HA-OEM TPM plan is based on production equipment segmentation into two categories, the AA and A.

The eight (8) processes that are executed with ‘AA’ equipment are depicted in Apdx Figure 7. ‘AA’ equipment categorization represents the equipment that is critical for the total production flow, meaning that either any breakdown will take too long to be fixed due to the technological complexity of the equipment and the spare part availability or that the equipment stoppage will cause more delays than usual. The latter may happen due to the production line set up, if for instance the equipment is part of a manufacturing cell comprised of more than one production process that will be immediately affected amplifying the delays. ‘AA’ equipment bears the highest attention of TPM plan. All other equipment with ‘A’ categorization represents the equipment that also need to be highly overlooked and maintained, since any breakdown stoppage, malfunction etc. will highly impact the production time, quality, and performance but the impact will not be that severe as in any AA equipment malfunction. We found out that although all ‘AA’ equipment re related to processes impacted by DLT, it can be the case that there are cases where processes with ‘A’ are also impacted by DLT, for instance the DTEC process as illustrated in Apdx Figure 7.

Based on OEE impact of DLT adoption, the production flow attributes that have been found to be affected, as presented in Table 9 and illustrated in Apdx Figure 7, are related to WIP inventory kept between processes, buffer stock, inventory that flows within first-in-first-out (FIFO) and inventory kept at S/M operations after the production processes that have been initially found to be impacted by DLT adoption.
Based on literature, OEE and production batch transferred inventories are among production processes factors that affect TT (Johnson, 2003). Buffer stock is defined as a default locked value. Buffer or else safety stock is kept for safety reasons, machine reliability included, and its value is not defined based on the production plan. Therefore, for the process that are affected by DLT adoption the respective safety stock that is assigned after those process is also affected.

Based on literature, improved OEE leads to reduced time needed to produce every singly batch and consequently the inventory that needs to be held after the process will be reduced as well (McKone, Schroeder, and O Cua,2001). Therefore, informants have been asked to identify which production attributes will be affected based on the processes that are expected to demonstrate improved OEE due to DLT adoption.

At this phase research data revealed that fifteen inventories that belong in various manufacturing streams are expected to be affected by DLT adoption. HA-OEM Informants have been asked to propose an estimated range of inventory level between ± 5%. After validating data derived by Plant A HA-OEM informants with Plant b, C, D HA-OEM informants it came up that for processes operated by 'AA' equipment, inventory kept after those processes is expected to be improved by 5% maximum. For processes operated by equipment that belong to 'A' equipment inventory is expected to be improved by 10% maximum, as presented in Table 9. Based on literature, based on OEE improvement manufacturing delivery performance is expected to be improved between 4,4% -14,6% (Kumar, Mani and Devraj, 2014; McKone, Schroeder, and O Cua,2001; Poppe. et al. 2017). Since the proposed range in literature is within the inventory level improvement range per HA-OEM manufacturing process, for calculation purposes, researchers decided to follow a common practice followed in such cases and consider the lowest threshold proposed in literature, meaning 4,4 % for al inventory improvements (Dupuis, 1999)

Inventory impacted by DLT adoption	VSM as-is	Decided Expected impact	Proposed impact	TPM category
FIFO after 'oven enamel' cell	144 item- 0,15 d	-4,4%	<5%	AA
S/M (after Εμαγιέ Ταψί Ρηχό	1940 item- 2,61 d	-4,4%	<5%	AA
Inventory of 'glued doors' after DTEC	300 item-1,06d	-4,4%	<10%	AA
Inventry of 'glued basic doors' after KUKA	332 items	-4,4%	<10%	AA
Invenotry of cavities	1044 item-1,06d	-4,4%	<5%	AA
Safety stock of 'cavities' after 'cavities firing'	max 262 item-0,26 d	-4,4%	<5%	Aa
S/M of 'enamel basic doors' after 'oven enamel' cell	540 item - 1,72 d	-4,4%	<5%	AA
JIS safety stock of 'HAGP' after 'oven enamel' cell	96 item-0,1 d	-4,4%	<5%	AA
JIS safety stock of 'Deep Tray' after 'oven enamel' cell	480 item-0,49 d	-4,4%	<5%	AA
JIS safety stock of ' Tray Carriage' after 'oven enamel' cell	96 item-0,34 d	-4,4%	<5%	AA
JIS safety stock of 'Deep Tray Carriage' after 'oven enamel' cell	96 item-0,34 d	-4,4%	<5%	AA
JIS of 'HAGP' after 'oven enamel' cell	1152 item-1,18 d	-4,4%	<5%	AA
JIS of 'Deep Tray' after 'oven enamel' cell	1152 item-1,18 d	-4,4%	<5%	AA
JIS of 'Tray Carriage' after 'oven enamel' cell	480 item-1,7 d	-4,4%	<5%	AA
JIS of 'Deep Tray Carriage' after 'oven enamel' cell	480 item-1,7 d	-4,4%	<5%	AA

Table 9: Production processes impact after DLT adoption

For every process we recognize and depict in VSM three distinct times, that are referred to the cycle time (CT), that represents how often a part is completed by the process, the process time (PT) needed before and after the process's internal WIP items are manufactured. CT and PT are by DLT adoption, since they are typical attributes of the process related with its technical characteristics such as the process or equipment set up. Process's PT is related with the demand quantity over the inventory kept before and after the process's WIP within the process cell. WIP inventory is defined based on the process's manufacturing capacity and the stock keeping units where the unprocessed goods are kept. Therefore, the sum of process's WIP and the inventory kept before and after the process remains unchanged irrespective of the process set up changes. It is related with the process capacity and the production planning, thus not affected by DLT adoption, since demand quantity is not affected by DLT adoption.

S/M after the processes that are impacted by DLT are affected in terms of items held within those operations. S/M is affected under the valid assumption that if DLT were to be applied then preventive maintenance could have been more accurate in terms of planning and that would result in increased reliability in 'AA' equipment related to the respective processes. Therefore, inventory kept after those process in the form SM set up would have been reduced (Roda and Macchi, 2019). However, not all inventories kept after process, even in the form of SM, are defined based on process's reliability. It can be the case that inventory is defined based on the planned operational time of the equipment related with the process. For instance, "cut-to-length' related equipment had been decided to operate once per week. That decision had been made based on inventory available for that process and is not related to the reliability of any process but is related to the availability of the material. Another case that one process operated by 'AA' equipment does not by default mean that inventories after the process will be impacted by DLT is when those inventories are calculated based on the production plan and are only too little affected by equipment maintenance that we will not consider it for our study, For instance, inventories kept after 'color painting' and 'white painting' are calculated based on production schedule. Defective products could come up based on specific operational failures of that process such as high humidity or errors in positioning the panels in the conveyor belt. Such errors have been considered that could create some defective products after the completion of the process and had been therefore considered inventory calculations of the inventory kept after the process. It is therefore obvious that DLT adoption would impact those inventories.

Production planning per product type is defined based on raw material availability, as depicted in Warehouse Inventory in VSM. If there is any delay in material receipt by vendors, then production planning is adjusted and another product type with sufficient warehouse inventory gets prioritized. Therefore, access to vendors inventory data based on DLT adoption will not affect the warehouse inventory held by HA-OEM but will only allow production planning review decisions to be made faster. Warehouse inventory number in VSM represent the day that raw material stays at the warehouse before it enters the production processes and acts as buffer against vendor's potential delivery SLA deviations. DLT adoption will not impact warehouse inventory, since real time access to vendors trusted data will not affect vendors (lead time) LT, which what eventually affect vendors capability to deliver based on agreed SLA. Another reason that DLT would not affect the warehouse inventory kept, is that DLT adoption would allow visibility on vendors data but would not directly impact the defective material produced and delivered by the vendors. The impact would be referred to near real time information on vendors operational processes. Therefore, shipment of defective materials could have been spotted at the source, before they reach at manufacturer premises. Thar would affect the manufacturer's purchasing policy or its relationships with the respective vendors but for the purpose of suRQ2.1 would not impact the warehouse inventory held. Defective material impact not only warehouse inventory but also inventories held before one process, since those material are transferred from the warehouse. If the manufacturer consequently identifies high percentage of defective materials delivered by a vendor, then decides for higher inventory from that material kept before one process affecting the manufacturing stream TT. However, DLT adoption is considered in our research to affect that inventory, since that could happen only if vendor's deficient deliveries could have been reduced. In our case the 'Door Glasses" is an example if material delivered by vendors and delivered from the warehouse before the 'DTEC' process. Since manufacturer has spotted higher material deficiencies than expected, has consciously decided to increase the respective 'Door Glasses inventory kept before the process, causing an inevitable increase in the respective manufacturing stream TT.

Visibility of intra-group entities (factories) data affects manufacturing leanness to the extent that this is referred not to material but to equipment spare parts. Raw material availability in another Plant of HA-OEM group would have the same impact as if a vendor failed to delivered, based on agreed SLA. However, in the case of an equipment spare part availability, that access to trusted information due to DLT adoption would bring to surface, would allow TPM plan to be adjusted accordingly opting to reduce the risk of equipment failure and consequently increase OEE. Inventory that moved on the conveyor belt is not affected by time. The time depicted on VSM represents the transfer time of the inventory and depends on the conveyor set up. That has been decided based on the process before the belt Takt Time and is not affected by DLT since Takt Time =

Total Available Production Time/ Average Customer Demand (Rother and Shook, 2003). Also, all milk run operations represent the delivery of material and supplies to assembly areas and no inventory improvement calculations are related to milk run operations. All production processes end up in a common assembly line. All manufacturing streams illustrated in Apdx Figure 7 and Apdx Figure 8 depict TT before the products reach the assembly line.

Manufacturing Streams	VSM as-is (TT) days	VSM to-be (TT) days	DLT impact (TT)
Cables	4,45	4,45	-
Ceramic Hobs	4,88	4,88	-
Front switch panel	5,76	5,76	-
Drawer	4,00	4,00	-
Side panel	8,97	8,97	-
Basic Doors	4,61	4,49	-2,60%
HAGP catalytic	1,64	1,63	-0,61%
Tray	2,93	2,82	-3,75%
Deep Tray	5,79	5,72	-1,21%
HAGP	1,70	1,64	-3,53%
Deep Tray Carriage	2,67	2,58	-3,37%
Tray Carriage	2,36	2,27	-3,81%
Cavities	2,60	2,55	-1,92%
Total TT	9,38	9,38	-

Table 10: Manufacturing streams affected by DLT adoption.

After applying inventory changes as illustrated in Table 9, through the VSM mapping presented in Apdx Figure 8 we can identify which manufacturing streams are affected by DLT adoption as illustrated in Table 10. Eight (8) out of thirteen (13) manufacturing streams demonstrated reduced TT by 0,61% to 3,81%, due to DLT adoption. Total TT (9,38 d) as the critical manufacturing stream have been found to remain unchanged, since its TT is defined by the slowest stream, meaning the ‘side panel’ stream, that does not include processes that are expected to be affected by DLT adoption.

All information flows switch from manual to electronic under the scenario of DLT adoption as depicted in Apdx Figure 8 Meaning that, any change in production schedule and order or plan is near-real time populated into all production processes and any other in-house supply chain stakeholder. Consequently, any respective decision making is accelerated since PPC reschedule report delays are highly diminished. The reason that not all processes which are linked with the information flows depicted in Apdx Figure 7, will be affected when information flow changes to electronic under the DLT adoption scenario, lies in the impact of WIP. Electronic information flow will accelerate decision making based on production volume planned and production shift plan reschedule but we argue that this will not cause an automatic WIP change. In our scenario we consider DLT adoption and investigate potential changes under the scenario of unchanged production volume plan and unchanged PPC schedule. WIP inventory after process, depicted with symbol "I" in Apdx Figures 7 and 8 represents the inventory kept based on production schedule under normal conditions on a regular production flow without any PPC review shocks that will cause inventory peaks or dips.

5. Conclusions and discussion

5.1 Conclusions based on subRQ1.1

To answer subRQ1.1 of "How do ecosystem types make fit to DLT ?" we initially reviewed the business ecosystem approach and how this evolved from business networks. That is necessary to define the business ecosystem key characteristics and realize how DLT networked approach can be extended to the ecosystem level. Even if it is beyond the scope of this study to provide a new business model definition, we reviewed the respective definitions along with the business ecosystem enablers. This gives us a deeper understanding on the key points they emphasize and spot those related to the DLT ecosystem conception. To answer the first part of subRQ1.1 on whether DLT works in all ecosystem types we selected to review the ecosystem types that their conceptualization is closer to the DLT ecosystem.

Seeing DLT as an innovative digital technology that designates the transactions between ecosystem members, we selected to examine the software, digital, technological, innovation, product and service ecosystem types as concepts closer to DLT ecosystem. We revealed their similarities to DLT business ecosystem and spotted their key attributes that make them to deviate from the DLT business ecosystem approach. From that comparison we deduced that each one of those ecosystems can be developed within the DLT business ecosystem. They can also be a subset of it but do not match DLT ecosystem key attributes and do not meet its objectives. We concluded that this can be achieved only by the business ecosystem approach. Therefore, answering the second part of subRQ1.1 on what ecosystem type is closer to DLT concept we reviewed the business ecosystem approach. To make it apparent we mapped the business ecosystem analogies to DLT ecosystem and identified the similarities between these two concepts. This study contributes to DLT ecosystem research by fostering an understanding of what ecosystem characteristics define its nature.[20]

[20] Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, 102143, https://doi.org/10.1016/j.techsoc.2022.102143

5.2 Conclusions based on subRQ1.2

Acknowledging the key business ecosystem characteristics, we dived deeper into the network effects created in DLT ecosystem to conclude that DLT architecture attributes and ecosystem actor number are crucial parameters of the ecosystem value generation security and sustainability. Our study revealed that ecosystem actor interactivity, ecosystem governance, actor's incentive for participation, value created and eventually DLT ecosystem sustainability are vastly affected by the roles and strategies of its actors. We defined that roles in DLT ecosystem are classified based on the dominant or non -dominant position that actors hold in it.

We identified that DLT architecture and actor roles are of major importance for ecosystem sustainability. In particular, power and attitude of dominant ecosystem players regarding ecosystem relationships are the fundamental pillars of DLT ecosystem sustainability. Niche players, analogical to business ecosystem literature, constitute the non-dominant group of actors in DLT ecosystem. Their participation in it is associated with ecosystem's scale up and sustainability potential. We argued that if niche actors feel that either contribute with low value creation or enjoy disproportional amount of value created by the network, they will be demotivated to participate in it and eventually undermine ecosystem's sustainability. It is therefore apparent that deep versus superficial collaboration is necessary for DLT ecosystem survival and that dominant DLT ecosystem actors need to push towards that direction. This conclusion is aligned with the common fate of all ecosystem actors that participate in DLT ecosystem.

We explored DLT ecosystem dynamics and under that prism we identified that ecosystem balance, robustness, productivity, niche creation, scalability, flexibility, actor aligned goal, activities and interdependency are DLT ecosystem sustainability factors. We eventually presented the endogenous and exogenous forces that affect DLT ecosystem evolution. We argued that co-evolution based in knowledge and resource transfer, DLT architecture, actor relationship types and role changes in a highly dynamic ecosystem environment form the main endogenous factors of evolution. On the other end market changes, changes in economic and social environment, technological change and regulations have been considered that constitute the respective exogenous factors.

5.3 Process model for the implicit effects of DLT adoption under a supply chain context (mRQ1)

Based on our findings we present a process model that incorporates the implicit effects of DLT adoption under a supply chain context to the business model dimensions for a manufacturing company. Based on the analysis of the cases, through the interviewees conducted, we seek and find answers regarding how DLT adoption for a manufacturer, under a supply chain context, leads to activities and decisions that affect organization's business model elements.

5.3.1 Building the process model for mRQ1.

Trust established through data openness, visibility and transparency, as well as supply chain collaboration lie in the center our research. Supply chain collaboration is a prerequisite not only from value network perspective but more than that from a DLT business ecosystem sustainability perspective. Due to the inherent characteristics of DLT, its adoption should support the ecosystem expansion prospect and facilitate deep collaboration among interacting actors. Network effects created by DLT business ecosystem expansion are vital for its sustainability. Trust is the main driver for DLT adoption and in our model its impact to supply collaboration is reflected on the business model dimensions. Our data show that DLT adoption in a manufacturing company initiates the transformation of those two main pillars of our analysis. Meaning the trust and supply chain collaboration, between the manufacturer and its external to the company supply chain interconnected parties, which consequently trigger the respective business model changes.

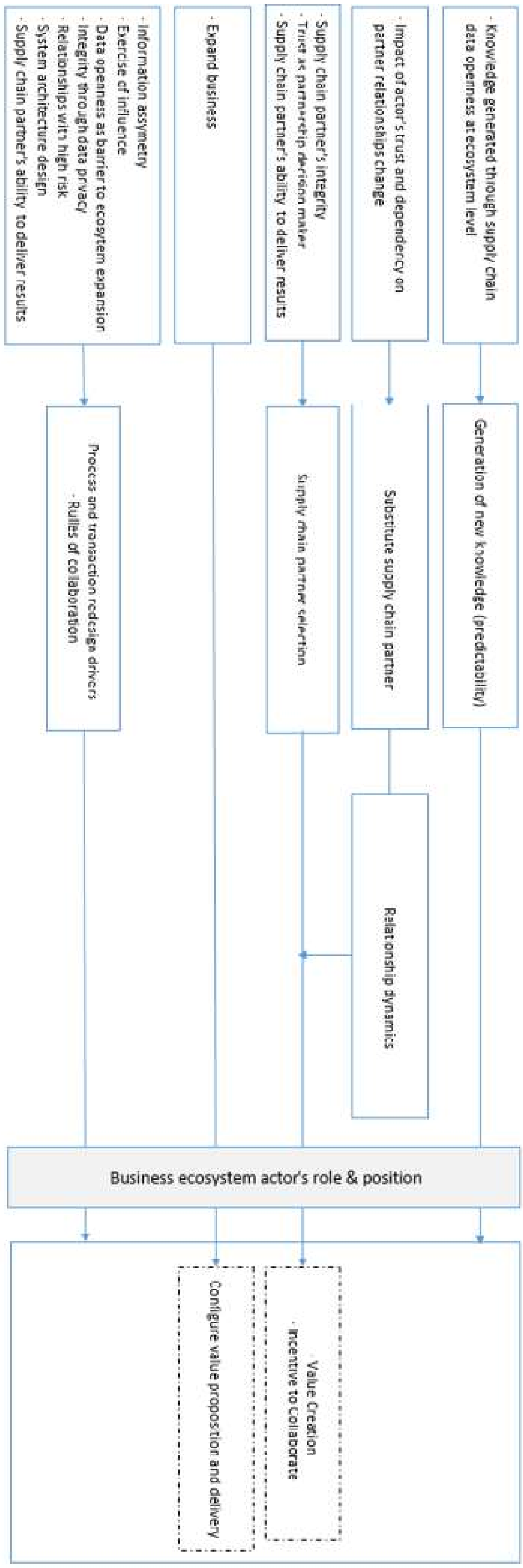


Figure 10: Process model for the implicit effects of DLT adoption(mRQ1)

The model presented in Figure 10 illustrates a dynamic rather than a static picture of a sequence of changes that lead to business model changes. It illustrates processes comprised of activities and intents that need to be continuously evaluated so that the respective business model dimension impact is constantly assessed. The model is constructed based on the relationship of the aggregate dimensions identified in data structure and their respective impact on the business mode dimensions, as illustrated in Apdx Table 3 in Appendix, that reflects business model dimensions impacted based on the multi-case study data structure presented in Figure 7. To structure the process model, we do not further distill the aggregate dimensions by seeking similarities nor we suggest concepts that further explain the impact of DLT adoption. We map the relationships of the aggregated dimensions with the business model impact they imply. Our model reveals a process grounded in the data, as exemplified by the data structure, that demonstrates the dynamic relationship among the emergent concepts, describes the DLT adoption under a supply context for manufacturing companies and their impact on the business model. At that phase we consult the literature to define the relationships between the aggregated dimensions, the factors that affect the business model and the activities that lead to the business model notions impacted.[21]

5.3.2 Process model for mRQ1 explained.

Partner selection is the first key step towards establishing supply chain partnership (Liu and Ran, 2020). From the point of network design and internal supply chain operations efficiency, finding suitable suppliers and other intermediaries to work with sets the basis for value chain configuration (Sha and Che, 2006). Criteria formulation, qualification and choice are, based on literature (De Boer, Labro, and Morlacchi, 2001), the three main stages of partner selection process. Based on our data all three are affected by DLT implementation. Data openness, transparency and visibility achieved through DLT seem to be strong candidates for supply chain partnership selection criteria. For non-established partner relationships, DLT adoption raises expectations for high trust level among interacting parties, yet from the partner selection phase. In that process manufacturers take into account their ecosystem position and the dependence

[21] Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

upon their partners. Through DLT adoption manufacturers emphasize on the possibility for a complete trusted assessment of future partners' competence. DLT is the mechanism for the manufacturers to establish direct trust. In alignment with DLT literature, it supports the decision-making process based on direct evidence that frames partner's qualification evaluation (Angelis and Ribeiro da Silva, 2019). Although the trust dimension of competence is clearly favored over the dimension of integrity, manufacturers base their supply partner selection decision on partners' consistency. Through DLT adoption data completeness of the latter is revealed yet in the qualification assessment phase.

The role of DLT seems to affect manufacturer's partnership decisions. Dependency upon a partner, actor's role in the supply chain, and its position in the ecosystem seem to have a joint effect along with the trust promised through DLT to the manufacturers decision to substitute one partner for another. Data openness, transparency and visibility seem to weigh significantly in potential partner relationship changes, to the extent that they promise higher trust levels. Both in the case of established and non-established relationships, partner selection and partner substitution decision seem to be affected by DLT adoption. In both cases the focus remains in the value creation aspect of the manufacturer. Data openness facilitates the assessment of both competence and integrity trust dimensions in manufacturer's relationships with its supply chain partners (Mayer, Davis and Schoorman, 1995). In addition to that it raises expectations for an iterative process of partner' performance evaluation based on trusted data.

Another business model impact of DLT adoption under a supply chain perspective, is the prospect of the DLT business ecosystem participants to generate new knowledge due to data visibility, information access and data exchanged achieved by DLT. 'Near-real-time' visibility is an obvious driver for end-to-end supply chain synchronization and optimization, whether it refers to optimizing physical goods distribution or synchronization of upstream supply chain activities (Somapa, Cools and Dullaert,2018). Companies, which interact through DLT, have to foresee the risks and design efficient actions to avoid deviations and mitigate the uncertainty (Li, Z. et al .2018). Our data also showed that manufacturers weigh the effects of the knowledge created through data exchange. Data openness raises concerns on how much data need to be opened and to whom. However, it has been undoubtedly proven that manufacturers rely on the fact that they can improve their own operations and advance their activities, which contribute to value creation, through the knowledge generated when other entities data are accessed and analyzed. The fact that the same applies for manufacturers' partners leads to a dual impact on the manufacturer's business model dimensions. In one hand DLT facilitates knowledge exchange and streamlines end-to-end supply chain operations by enhancing partners' ability to deliver results, on the other hand it raises concerns around data privacy based on the data openness required.

In a highly dynamic environment, relationships among ecosystem actors are not static but are subject to continuous change. Our data showed that the role, dependency and position of the supply chain direct and indirect partners, is of great significance and along with the data openness strategy of each actor define the value network dimension of the business model. Due to data privacy concerns, triggered by potential relationship changes, manufacturers are based on strict contractual agreements to prevent potential data leakage. They view data openness, that is by default required for DLT adoption, as a barrier to business ecosystem expansion. On the top of that our data showed that data sharing imposed by regulatory bodies actually defines manufacturers' data openness threshold under any DLT architecture specification. However, it seems paradoxical that although the need-to-know basis and the data openness threshold seem to define manufacturer's data openness strategy, they refer to data openness to request visibility into their partners' data. This is particularly evident in the case of re-establishing broken relationships. Given the fact that based on literature, in business network trust's role is a precondition rather than a cooperation driver (Gausdal, Svare and Möllering, 2016), we conclude that DLT impacts value network when it is viewed and assessed along with three other attributes. That are, the role and the position that an actor holds in the ecosystem, the degree of influence and control that the manufacturer can exercise on their interacting actors and the level of information asymmetry identified among interacting actors. The higher the information asymmetry identified among partners, the greater influence that the manufacturer can exercised to its partners, especially when significant ecosystem position gap among partners is identified. Under that condition the manufacturer is keen to lift his data openness concerns and reduce trust thresholds in order to achieve deeper collaboration with its partners through DLT adoption. Our data revealed that in any other case potential benefits in value network and value creation promised through DLT adoption are constantly evaluated on a benefit vs risk logic. Under that logic no obvious indication of which of two will prevail seem to exist but with indication towards manufacturer's risk averse attitude.

At that point it is important to underline the risk of a superficial collaboration among DLT business ecosystem partners. Any such collaboration attribute does not enhance the prospect of a sustainable DLT business ecosystem, since niche ecosystem actors are pushed to collaborate with dominant manufacturer (Iansiti and Levien,2004). The key to avoid superficial collaboration, by incentivizing actors to collaborate and achieve the golden ratio between privacy concerns and data openness necessary for DLT adoption, lies in the DLT architecture design. The system architecture that impacts the transactional dimension of the business model will define the rules of collaboration. Those rules will affect the degree up to which value creation and value network through collaboration incentives and value creation business model dimension will be impacted. The extent to which manufacturer's transaction redesign drivers meet the objectives and the concerns of all actors, will define the impact on the value creation and value network business model dimensions.

When a manufacturer targets to expand its business or re-configure its product, then the data openness tilts the balance between benefit vs cost towards the former, with the latter to be mainly considered under the aspect of a lost opportunity or potential failure to address customer needs. The value proposition crystallizes the hypothesis of the company formulated into what is promised to be delivered to consumers and how much they will be charged for it (Salum, 2019). Each time that the value proposition is re-configured manufacturers are keen to open more data than usual with their 1st tier material supplier and with the intermediaries that constitute the market channels, irrespective of the level of trust established with them up to that point. Regarding the manufacturer's relationship with its market intermediaries, or else the market channel dimension as mentioned in most business model frameworks (Osterwalder, A. and Pigneur, Y. 2010), data openness and established trust do not seem to affect each other. DLT seems to be seen as the mean to facilitate transactions with these types of actors, rather than as the relationship driver through trust establishment promised. This is yet another clear indication that the role of the actors impacts value proposition reconfiguration and value delivery related decisions. In short, the value delivery along with the value proposition business model dimensions have been proven to drive data openness through DLT so that the manufacturers meet their business expansion objective.

5.4 Process model for the in-house supply chain DLT adoption and business model impact analysis (mRQ2)

Based on our findings we develop a process model that brings together the aggregated dimensions needed to be considered to assess the factors that resonate DLT adoption at in-house supply chain level and their inevitable impact on business model dimensions. Establishing and maintaining trust and trustworthiness, for information sharing, when in-house supply chain entities interact with each other and with external bodies, is a dynamic process that shapes the organization's business model dimensions.

5.4.1 Building the process model for mRQ2.

Our data show that in a manufacturing MTO supply chain, in-house supply chain departments' intention to trust is not static. It is rather transformed based on the measured impact of all supply chain interconnected parties' performance on supply chain operation. Emphasis is given in the production system efficiency achieved as well as into the data driven decisions taken for the supply chain continuous improvement. Competence and integrity, being among the most widely recognized dimensions of the 'trust-in-organization' models (Mayer, Davis and Schoorman, 1995; Falcone and Castelfranchi, 2001) are the key parameters that gauge the level of trust achieved in in-house supply chain departments through their collaboration and their interaction with external supply chain entities.

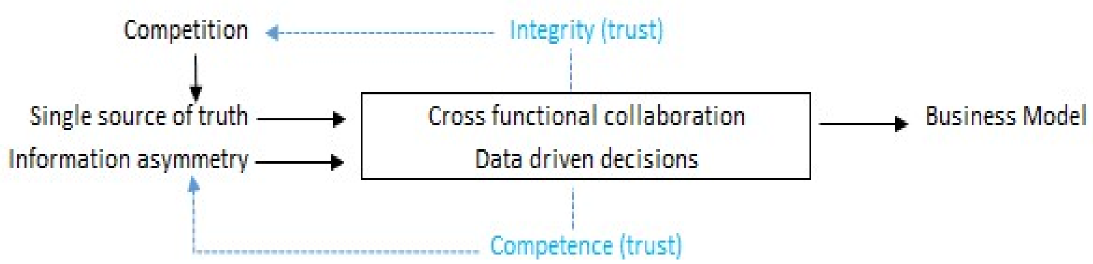


Figure 11: Process model for in-house supply chain DLT adoption(mRQ2)

Relational dynamics of DLT in-house adoption overarching themes, as exemplified by the data structure and by their effect on business model dimensions, are presented in Figure 11. Our data show that in a highly efficient supply chain, that has achieved high level of information system integration and applies high end supply chain practices, elite informants' perception indicates strong trust both to the internal and external to the company interrelated parties.

5.4.2 Process model for mRQ2 explained.

Breaches of trust and some competition among interacting parties, caused by behaviors that indicate potentially conflicting financial incentives have been revealed into the inside-out supply chain interactions. Opportunistically driven incentives of some vendors not to meet the agreed SLAs raises integrity concerns. Lack of visibility in the end-to end inbound material or service delivery processes increases the risk of internal supply chain operation deviations and feeds the mistrust among the interacting parties. Supply chain related decisions based on undisputable, trusted and near-real time available data, would mitigate the consequences of competitive behavior. Trusted information exchange and data visibility among interacting parties would immediately expose the risks and reveal the implications yet at the initial phase of any such behavior.

In addition to that, as revealed by informants, collaboration between same company group entities or plants is impacted by conflict of interests driven by contract assignment decisions. All interviewees agreed that in a well-structured supply chain that captures a great deal of trusted data, the single source of truth should be there to expose any such competitive behaviors that put at risk in-house supply chain operations and undermine their efficiency. Informants revealed that the organization seems to rely on decisions that are based on specific, rigid processes, such as periodical extensive audits and metric bases reports, that reveal measurable findings. Although capturing data in such a well-structured way enhances data driven decision making, the fact that data record gaps, information sharing inefficiencies, resource consuming audits and lack of near 'real-time' information exchange phenomena had been observed, lay the ground for in-efficiencies in data driven decisions and cross functional collaboration. The risk of retrieving outdated or incorrect information, the need for near-real time visibility of the appropriate data without resource consuming processes to collect them, unleashes the DLT adoption potential through its single source of truth attribute. The impact of single source of truth into in-house supply chain cross functional collaboration, relies mainly in trustworthiness enhancement through the elimination of arguments and doubts when the appropriate tamperproof information is accessed by all in-house supply chain involved parties. On the top of that. the fact that with DLT identical information is not double entered neither distributed with delay nor get manipulated, facilitates interacting supply chain parties to gain visibility on the same trusted information and collaborate effectively and efficiently.

According to our data, the fact that supply chain actors hold incomplete, more, or superior information than their interacting parties makes information asymmetry as the overarching factor that impacts the trust level in supply chain. Our focus in supply chain related to information held and shared exclusively among company departments revealed inefficiencies at the information mining and sharing processes. All necessary information is usually kept in highly integrated centrally controlled information systems. However, the fact that information flow follows a specific, rigid, though well-structured, diffusion path may often leave supply chain departments temporary with incomplete information until overcoming data analysis or data matching delays. Decisions, such as those related to sharing customer feedback analysis, scenarios such as production planning data needed for PPC reviews, inter-departmental collaboration capabilities affected by data synchronization between production line data, maintenance and internal communication inefficiencies due to misperceptions or delays in data matching reveal 'effort-level' information asymmetries. Based on literature, the fact that the effort level of an actor is not completely known by another actor affects the performance of the supply chain (Zhao and Wei. 2014; Qian, et al. 2012). At that point what is at stake is the resource-efficient near-real time access to trusted information kept in the company's databases. Reviewing decisions, creating communication loops to clarify data analysis, rework scenarios and in general review supply chain decisions lead not only to supply chain inefficiencies but more than that may lead to supply chain disruptions. Supply chain departments need to collaborate effectively and fast so that any information exchange will allow them to take on time the most appropriate decisions. Data visibility and trust on data have been revealed to cause delays and increased risk in taking decisions before all necessary data are available (Mohammadali, Atour and Canel-Depitre, 2020).

Maintenance service providers hold superior knowledge to the respective problem-solving activities and that fuels information asymmetry related due to lack of data openness and visibility between the interacting parties. Stronger emphasis on the visibility of trusted data has been given by the interviewees into the information sharing and exchange mechanism between company departments, e.g., planning, inventory management, PPC and the external manufacturers and material suppliers. Under those conditions a twofold source of supply chain disruption risk has been revealed. The first is that limited visibility on trusted information either regarding vendors' supply chain processes, such as production processes, conformity with specifications, inventory, capacity etc., or limited visibility in the end-to-end inbound material processes is the main source of inbound delivery SLA deviations, that consequently increase the production disruption risk. The second, is the coordination mechanism of that asymmetry.

Although Inside-out data openness and limited information system integration are actions that push towards an efficient coordination, they leave significant space for improvement. Getting both interacting parties to open their data through a tamperproof data exchange process would increase not only the visibility and transparency in their transactions but would also act as a supply chain disruption proactive mechanism which is expected to eradicate vendors' SLA deviations right in the source. Cross functional collaboration is directly impacted when inbound service or material flow related are subject to unpredicted change. In turn, all related data driven decisions, such as PPC and asset maintenance are affected. Information asymmetry driven supply chain disruptions are met in material supply and flow process around the inbound supply chain zone and the maintenance operations.

In a highly efficient supply chain, we take as given that company takes all necessary actions to ensure high performance. Management best practices and supporting mechanisms are expected to be applied when we discuss about high supply chain performance. Although DLT can contribute into high supply chain performance (Wang, Chen and Zghari-Sales, 2020), its main impact is to resolve the trust issues among the interacting parties, enhance trust in transactions and allow parties with low trust to each other to collaborate. After all, it is not the DLT that will make the supply chain highly efficient. Highly efficient supply chains operate so far without any DLT implementation. It is the space that competitive behaviors leave, through the effective exploitation of a single source of truth, and the impact of information asymmetry that reveal the trust gaps when we look the in-house supply chain efficiency.

Literature identifies trust as an important antecedent of inter-organizational network formation (Brass, et. al. 2004). Therefore, the trust is the central notion in the network that lays the ground for DLT adoption. We consider the aspects of cooperation between all intracompany supply chain departments and functions and the intersections of each internal supply chain process with external entities as the main pillars of the supply chain efficiency that reveal the trust gaps ins supply chain. One of the most prevalent findings of our data is that in-house supply chain entities demonstrate high trust into the data kept in the company and into their vendors. To some extent this is somehow expected for a top in-house supply chain performer. However, competitive behaviors raise integrity concerns and that is what needs to be evaluated when data driven supply chain decisions are made. The intentional choice of a trustee to behave in a certain way (Mayer, Davis and Schoorman, 1995), in our case driven by competition related motives, may well increase the supply chain risk with regards to internal supply chain operations. Competitive behavior demonstrated either between company departments, among intra-group entities or even between external and internal to the company entities needs to be prevented from provoking inefficiencies at in-house supply chain department cross functional collaboration. DLT finds ground for adoption due to the promised enhancement of the single source of truth and the elimination of the integrity variable as trust concern factor.

Apart from the internal supply chain departments the capability of the external suppliers to deliver and perform based on mutually agreed SLAs and specifications set, need to be taken as given for supply chain efficiency. We do not argue, nor did the interviewees, that in an efficient supply chain vendors and departments are selected based on their ability to perform under high standards and that their performance is closely monitored and constantly evaluated. The fact that information asymmetry between competent supply chain actors has been observed, reveals the role of trust to ensure competence. The role of the DLT lies in that of a mechanism which will ensure that competent interacting actors will perform their tasks meeting the standards set. Competence may change over time (Lymperopoulos, Chaniotakis and Rigopoulou, 2010). By gaining experience, companies improve certain skills and their knowledge. Consequently, they become more competent. Data openness, bilateral visibility and transparency on interacting actors' data, reduces information asymmetry pushing them to become more competent. Therefore, it becomes obvious that trust plays a central role in achieving high level of cross functional collaboration and enhances decisions. These can be met under the condition of access to trusted data when information asymmetry, competitive behaviors and gaps in single source of truth phenomena are observed in in-house supply chain operations.

5.4.3 In-house supply chain DLT adoption impact on business model

To evaluate the impact of DLT adoption at in-house supply chain operations on the business model, we will assess the respective impact of the five aggregated dimensions that have been proven to drive DLT adoption. For that reason, we selected to use the Velu (2018) business model architecture and initially define which one of the four business model dimensions is affected and to what extent. Since in-house supply chain operations mainly refer to product configuration and production, the value creation dimension had been originally expected to be the most impacted dimension. However, in-house supply chain DLT adoption also affects the relationships between internal and external partners and the degree to which the product characteristics that a customer expects to receive by using the product are successfully reflected in it. Finally, DLT adoption affects how much value will be retained due the elimination of the resource consuming inefficiencies that diminish the value actually captured.

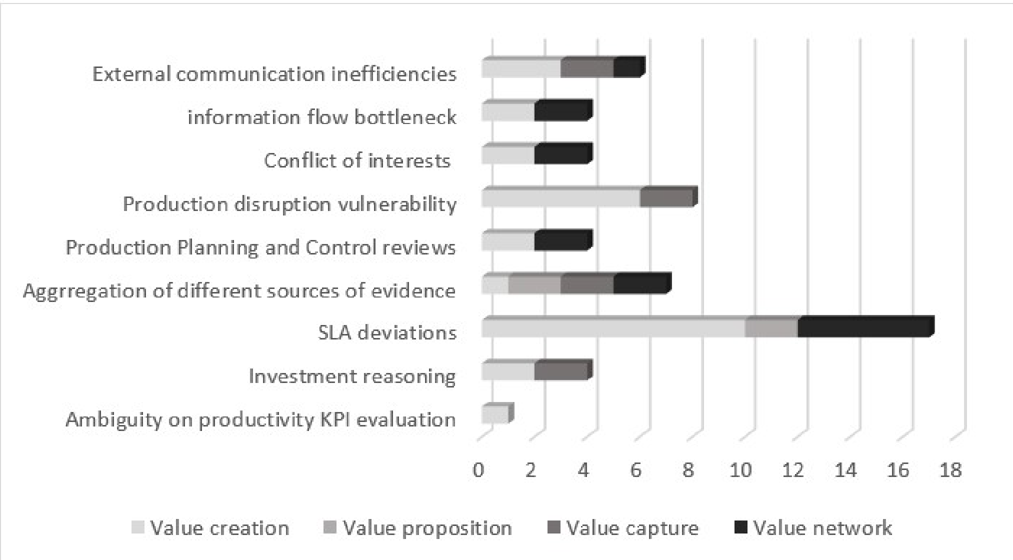


Figure 12: Impact of in-house supply chain DLT adoption 2nd order Themes on business model (mRQ2)

After assigning the business model dimension that is impacted by each one of the first order themes revealed in data structure, as presented in Figure 8, we can end up defining the respective weight of the second order concepts and the aggregated dimensions. The value of the coding procedure followed for the data structure lies not only in the definition of the aggregated dimensions but mainly in the exploration of the source of those dimensions. In our case it has been found that, 11 out of the 27 1st order concepts affect SLA deviation. The latter as presented in Figure 12 impacts most of the business model dimensions followed by Production Disruption Vulnerability. In Figure 12 it is illustrated that Information Asymmetry has, by far, the higher impact on business model, while from data structure, as in Figure 13, we can note that these dimensions are impacted exclusively or combinatory by 16 out of the 27 1st order concepts. It is therefore obvious that not all aggregated dimensions weigh the same in regard to their impact on into the business model.

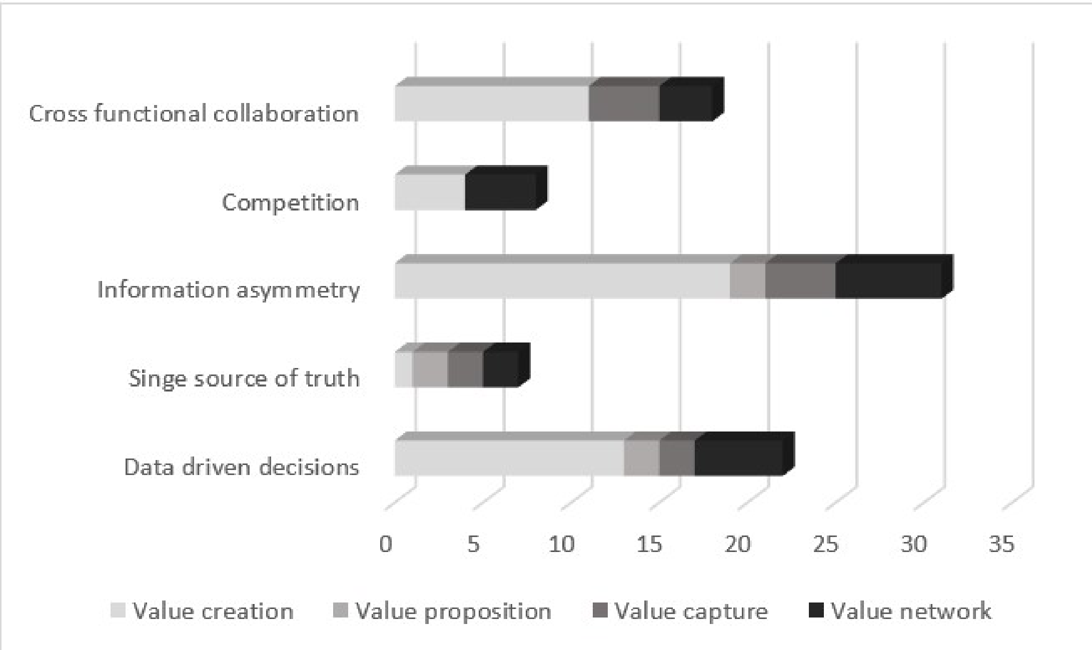


Figure 13: Impact of in-house supply chain DLT adoption aggregate dimensions on business model (mRQ2)

As presented in Figure 14, value creation business model dimension is heavily impacted, as expected, by most of the 2nd order concepts and the aggregated dimensions, followed by the value network business model dimension. In-house supply chain DLT adoption mainly impacts, as expected, the value creation dimension of the business model. In-house supply chain operations by default refer to the distinctive competences of the manufacturer to produce its products. The operational dimension of the business model that is associated with the manufacturer's resources, activities and particularly in the production system related performing activities, have been emphasized by the informants to be mainly linked with the in-house supply chain DLT adoption (Fjeldstad and Snow, 2018). A highly efficient and effective in-house supply chain operation mechanism demonstrates among others without the need of any DLT adoption high level of efficiency into load balancing the production system operations. On the top of that it mitigates the production disruption risks caused by cross functional collaboration or by its interaction with any internal and external to the company entity. Our data showed that inefficiencies, that are mainly triggered by information asymmetry, competition and lack of single source of truth, cause supply chain efficiency gaps and increase the risk of value creation deviations.

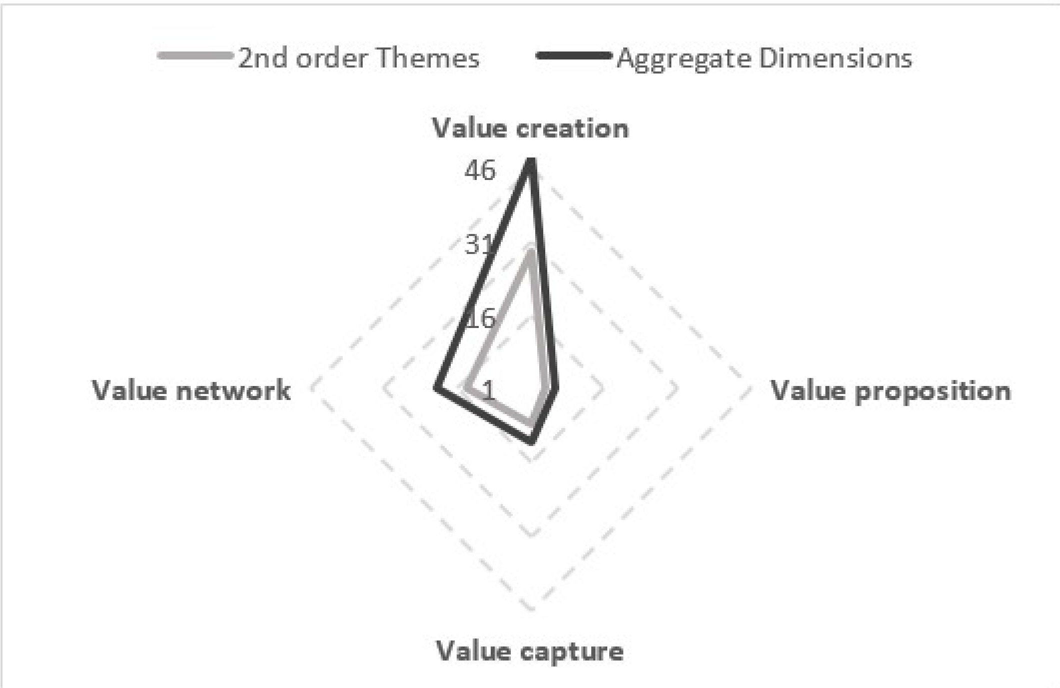


Figure 14: Overall Impact on in-house supply chain DLT adoption on business model dimensions (mRQ2)

Value network, as described by Velu (2018) business model architecture, is the dimension that refers to the network relationship aspect of the organization and underlines the value exchanges with entities external to the company. Under the aspect of in-house supply chain DLT adoption, value network dimension spotlights the role of entities external to the company that interact with the in-house supply chain departments. Data openness, and access to trusted information have been identified, by our data, to be the key pain reliefs in inefficiencies caused mainly due to information asymmetry and competitive behavior among interacting parties. Although an organization that operates a highly efficient in-house supply chain might take actions, such as information system integration, close collaboration and vendor's metrics-based performance monitoring, lack of bilateral trusted information flow and visibility through data openness leave much space for improvement. Value network refers to the role that the firm plays in the network (Shafer, Smith and Linder, 2005). Our data revealed strong emphasis into actor relationships established based on the dependency and the power imbalance between the interacting parties. Those two attributes resonate DLT adoption, since they lay the ground for deeper collaboration between the manufacturer and its material and service providers. 'Manufacturer-vendor' relationship establishment, may be a well-structured process in high end supply chains, especially in the onboarding phase. However, DLT adoption not only fills the gaps towards preventing supply chain deviations but also deepens the collaboration among interacting parties moving away any power game or competitive driven behaviors.

Value proposition and value capture lag significantly in the business model impact of DLT in-house supply chain adoption. What resonates DLT in-house supply chain adoption lies merely in the production related processes and their respective actor relationships required based on interacting parties' trust and transaction visibility. Value capture is affected by DLT in-house supply chain adoption initiatives triggered by cost structure related inefficiencies. For instance, inefficiencies in organization's departments that are revealed through periodical internal audits impact the cost architecture, investment planning and the financial decision aspect of the business model. The same applies in the case of delays in information, document matching and approvals as well as in external communication that impact the cost structure of the organization. Value capture had been originally expected to be affected by material or finished product quality related issues but our data revealed that quality issues do not exceed the acceptable limits and the respective KPIs have been found not to raise any quality issue related concerns at any phase of the in-house supply chain activities.

Value proposition refers to organization’s customers and their values (Teece, 2010; Johnson, Christensen and Kagermann, 2008). For the first, DLT adoption for in-house supply chain activities points out the desired customers’ visibility and trust into company’s in-house supply chain activities. For instance, in the case of high-end technological products and especially in an engineer-to-order supply chain, trust on specification conformity and access into production system for monitoring purposes may well be considered as mandatory prerequisite contractual terms. In a MTO supply chain, customers’ low need for a deep insight into manufacturers in-house supply chain operations does not seem to justify in-house supply chain DLT adoption. This need has only been identified at the point that the manufacturer needs to capture customer feedback in regard to observed deviations between expected and delivered customer value. In that case DLT impacts the mechanism that the customer feedback captured is diffused appropriately and timely among all in-house supply chain entities.

DLT adoption triggers value proposition changes by making the manufacturer confident that the appropriate knowledge generated from customer feedback analysis will timely cause the appropriate corrective and preventive in-house supply chain actions and the value proposition will be eventually improved. It is worth mentioning that in regard to DLT adoption at manufacturer’s in-house supply chain level, value proposition could have also been impacted by his visibility and trust into his upstream material and service providers. Although this effect seems to be included in the impact that DLT adoption causes to the value creation dimension of the business model, we need to denote that delivering the ‘right’ product is of the same importance as of delivering it on the ‘right’ time. Violating the latter impacts the value proposition dimension of the business model. In house supply chain DLT adoption has been proven from our analysis, to affect parameters such as quality assurance of incoming material, temporary repeated production system inefficiencies not revealed in audits and arguments on audit results. These in-house supply chain specifications might lead to in-house supply chain delays that will be further reflected into the timely delivery of the product to the end customer and consequently impact the overall value proposition.

5.5 Conclusions based on subRQ2.1

In our research we built upon the findings of the in-house DLT adoption causations to investigate to what extend could DLT adoption impact manufacturing leanness. Under the assumption that DLT adoption will only affect the information flow, we applied DLT adoption scenario in a home appliance MTO global manufacturer, that operates a highly efficient supply chain, has already adopted most of the modern lean manufacturing methods and demonstrates high level of information system integration. The manufacturer studied had been selected under the conceptualization that in-house supply chain leaves limited to no obvious reasons for DLT adoption. Consequently, one could argue that DLT adoption impact on information flow only does not conceal any supply chain inefficiencies that could have been dealt with any material flow improvement lean method. Researchers employed the value stream mapping methodology (VSM), to depict the simulated future state under our assumptions.

Findings emerged from that simulation revealed that the main impact of DLT in-house adoption causation is expected to be on OEE improvement. Even though a manufacturer might demonstrate high OEE performance, DLT adoption will still impact OEE and consequently reduce the inventories kept or transferred after the respected processes affected by thy improved equipment effectiveness. Though not all inventories after the respective processes had been found to be affected by equipment reliability. OEE and inventories kept or transferred in any segment of the production flow e.g., WIP inventory kept between processes, buffer stock, inventory that flows within first-in-first-out (FIFO), inventory kept at S/M operations, affect TT (Johnson, 2003). In our research manufacturing leanness had been investigated under the prism of inventory and TT improvement. Most manufacturing steams had been found to be affected in terms of TT improvement between 0,61%-3.81%.

TT improvement results along with the fact that our research opts to explore the potential of manufacturing leanness improvement due to DLT adoption in an organization that already applies lean improvement methodologies focusing solely on information flow change, allow us to argue that DLT impact comes complementary to any other Industry 4.0 solution. Manufacturing leanness improving dilemma should not be DLT or nothing. Value added to in-house supply chain operations, due to DLT adoption, reveals that it should not be seen as a stand-alone solution but rather as

combination with other systems or data sharing processes already in place. DLT, under in-house supply chain context, had been proven to be valuable even in the case of high supply chain management integration and that enhances the complement role of DLT. That fact that that in the case studied other high end information sharing systems had already been in place and DLT adoption still contributed to manufacturing leanness indicates that it DLT supports the I 4.0
connectivity approach.

Moreover, results indicate that DLT provide an additional option for optimization. Classic DLT argument is that it resolves trust issues between interacting actors. However, beyond that it relates the transaction focused approach as altered due to DLT adoption, to manufacturing optimization. Without applying any lean material flow improvement methodology, it has been found that TT is expected to improve due to DLT adoption. Thus, only due to the impact on information flow by DLT adoption under an in-house supply chain context, TT in most manufacturing streams has been found to be improved. TT improvement is one of the major targets of manufacturing and production flow improvements target through by classical lean methodologies. In short, we could generalize that DLT adoption at in-house supply chain context is not the profound manufacturing optimization technique that could easily be applicable to a manufacturing supply chain. However, its complementary role to extant information systems and its power to provide optimization, allow us to conclude that even if it is a technology hard to be implemented, since it is still in a preliminary stage of development, when adopted may have significant impact in manufacturing leanness.

6. Managerial implications and research limitations

6.1 Managerial implications

In managerial terms this study helps manufacturing business managers to understand how business model dimensions are affected by DLT adoption at supply chain level. Our results indicate that irrespective of the efficiency of the supply chain strategies and methodologies followed in a manufacturing MTO organization, issues related with trust among interacting parties leave space for DLT adoption. Through the process models proposed, managers can assess the impact of DLT adoption on business model. Moreover, they can assess which business model dimensions will be impacted based on the preferred DLT architecture design and DLT adoption decisions related to endogenous and exogenous factors. Operational efficiency improvement drivers and configuration of relationships among interacting actors in a highly dynamic environment has been proven, based on our data, to affect in different ways the business model.

Our results indicate that irrespective of the primary scope of DLT adoption at supply chain level, it cannot eventually affect less than two business model dimensions among the value creation, value proposition value delivery and value network dimensions. Actor's role, dependency and position in business ecosystem has been proven to be of critical importance in any managerial decision related to DLT adoption in manufacturer's supply chain. Our data revealed that interacting parties' role in the ecosystem act as a filter in those decisions. This parameter contributes and refines the degree of business model impact triggered by manufacturers DLT adoption decisions drivers. This research helps managers understand the gaps in cross functional collaboration and enhanced data driven decision-making that is triggered by specific attributes which justify DLT adoption at in-house supply chain level. Our results highlight the dimensions of trust impacted by DLT adoption drivers. We present interactions between DLT adoption causations and trust dimensions that formulate a managerial monitoring process of evaluating to what extent DLT adoption impacts supply chain operational efficiency. We provide decision makers a solid understanding of the business model impact magnitude triggered, by DLT adoption at supply chain level, to aid their judgement about potential business model change or innovation decisions.

6.2 Future research and limitations

The limitations of the study that call for further research are mainly related to the size of the company and the manufacturing model of the company. Studying LEs allows the researchers to be more confident that complex supply chains face more challenges on the road to their new digitalization status. Consequently, we can be more confident that more aspects that might affect organization's business model are covered. This approach offers higher possibility for findings generalization. However, not all analogies are maintained in the case of SMEs. Cost structure, supply chain flexibility and complexity are parameters that differentiate the weight of decision-making parameters for DLT adoption. We can by no means claim that endogenous or exogenous supply chain DLT adoption drivers simplify the decision-making process in SMEs, due to reduced supply chain complexity. We can only argue that exploring the implicit effects of DLT to SME manufacturers' business model would supplement the process model proposed. Under the business ecosystem perception adopted in our study, SMEs usually constitute the critical part of the niche ecosystem actors. If we add this to the fact that manufacturer's role and ecosystem position massively affect the degree of DLT impact on business model dimensions, when studying SMEs manufacturers instead of LEs we could reveal potential differentiation of the process model proposed in this study.

In the multiple case studies sample, when investigating the implicit effects in business model that stem from DLT adoption, selected manufacturing organizations operate under the MTO and MTS strategies, since based on literature are considered to be the two most prevalent manufacturing strategies. DLT implementation for manufacturers that adopt ETO supply chain strategy would reveal to what extent the proposed process model would comply with the information management needs and the ecosystem characteristics of a supply chain type with a 'pure degree of customization' and high product complexity. Various ETO types have also been proposed in literature. All ETO types focus on the amount of responsibility that is managed in-house the core competencies, the supplier relationships, environment and types of risk (Amaro, Hendry, and Kingsman, 1999; Hicks and McGovern, 2001). It is therefore apparent that trust, being a fundamental DLT implementation driver, along with data openness, as key activity for DLT adoption, and ecosystem dimensions, such as partner relationships are massively affected under a different format in ETO supply chain.

When investigating the in-house supply chain DLT adoption causation we consider that an organization belongs to the RBC category of MTO industry and not in the VMC. The latter are expected to demonstrate by default a more grounded reasoning for in-house supply chain DLT adoption. VMCs need to achieve higher cross functional collaboration, due to its continuous efforts to design and configure manufacturing of new or modified products and deal with varying production loads (Kingsman and Souza, 1997). The level of re-configurations and frequency of production circles are expected to affect job shop configuration. For instance, based on potential job shop routing set up, which is a good fit for a VMC, jobs can start and finish at any work center, allowing complete freedom and customization (Stevenson, Hendry and Kingsman, 2005). In addition to that, highly customized products might imply higher inbound delivery lead times and different supplier order and inventory replenishment strategies. Those essential MTO attribute differentiations are highly possible to counterbalance some of the in-house supply chain adoption drivers and consequently affect their business model impact.

The absence of postponement manufacturing strategy in the case selected, removes a critical touchpoint between the demand captured at market level and the operational decisions at the decoupling point. However, future research into a MTO manufacturing company, which applies late configuration strategy and TOC methodology could reveal if and how the decoupling point can be transferred upstream or downstream to the supply chain and if its positioning against the in-house supply chain bottleneck could affect DLT adoption.

Finally, although literature emphasizes the relationship between WIP inventory, TT and manufacturing leanness there are also other metrics that could be considered to investigate the impact of in-house supply chain DLT adoption and leanness. For instance, future studies could investigate the composite shop floor metric of productivity and the performance indicator of quality as indicators that could depict the relationship between DLT adoption and leanness improvement.

Appendix

Q1	Based on what *key criteria* do you select your inbound and outbound material and service supply chain partners ?
Q2	To what degree *data* openess, transparency and visibility affects your decision to *partner* with a *key supply chain partner* ?
Q3	To what degree *data* openess, transparency and visibility affects the decision to *partner* with a *non-key supply chain partner* ?
Q4	What do you assess in your former supply chain partners when you decide to *re-partner* with them ?
Q5	What in particular do you assess in your *former* supply chain partners, when you are about to re-partner with them and assign them a role *critical* to your supply chain ?
Q6	Comparing the established trust between your current *key partner* and the expecation that another candidate key partner promises *higher level of trust through data openness*, transparency and visibility, to what extend does it affect your decision to *substitute* your current key partner ?
Q7	Comparing the established trust between your current *non-key partner* and the expecation that another candidate key partner promises *higher level of trust through data openness*, transparency and visibility, to what extend does it affect your decision to *substitute* your current *non-key* partner ?
Q8	What eradicates your mistrust against your external supply chain partners ?
Q9	"We favor partner *competence* derived from direct evidence *against* partner *integrity* derived from reputational evidence" ? To what degree does it apply in your company for the following business ecosystem entities ?
Q10	What actions do you take for your current partners each time a *key supply chain partner* exits partnership with your company, for any reason, and establishes a relationship with a competitor ?
Q11	How do you elaborate on 'near-real-time' visibility into your *2nd tier material* suppliers' operations ?
Q12	How do you elaborate on 'near-real-time' visibility into your *2nd tier service* suppliers' operations ?
Q13	To what degree does 'near-real-time' visibility and transparency into your 2nd tier suppliers' data affects your decision to partner with the respective 1st tier suppliers, for the partner categories listed below ?
Q14	To what degree are you keen to redesign, at least partially, your data management process towards *opening more data* to the external entities listed below, in order to improve value delivery and proposition ?
Q15	In order to *meet your value proposition objective*, to what degree ,are you keen to *open a substantial amount of data* to the external entities listed below, given the fact that they are *highly competent* to leverage and elaborate on your data ?
Q16	What *data sharing strategy* do you follow with *dominant business ecosystem partners* that you do not govern or cannot manipulate the relationship with them ?
Q17	How much is your decision to collaborate with the prefered vendor, as listed below, affected by the fact that you will need to *open part of your operational data,* given that your prefered vendor is already cooperating with your competitors ?
Q18	What weighs most in your decision to *temporarilly collaborate with a competitor* and inevitably *share part of your operational data* for the sake of efficient value proposition and delivery?
Q19	Appart from signing a non-disclosure agreement (NDA) and GDPR, what do you assess before you *share data* with *important ecosystem actors*, eg. investors, research institutions, regulatory bodies etc, given the fact that you do not trust their data tamper proof capabilities or intentions ?
Q20	To what degree do you *open more data than usual* to the following external entities, when you decide to join an new business ecosystem, in order to *explore new market opportunities* (new market channels) ?
Q21	What factors, if any, weigh most in your decision to *open more data than usual,* in order to *incentivize more business ecosystem actors* to collaborate with your company ?
Q22	"The *higher the number* of business ecosystem **actors** that we collaborate with, *the more data* we are keen to share with them, to fuel that ecosystem expansion dynamic". To what degree does that statement apply in your company ?
Q23	"The *more trust* we establish with our *key-partners* the *less strict we* are with them when they deviate from the agreed service level agreement". To what degree does that statement apply to your *key-partners* listed below ?
Q24	"The *more trust* we establish with our *non-key-partners* the *less strict* we are with them when they deviate from agreed service level agreement". To what degree does that statement apply to your *non-key partners* listed below ?
Q25	In order to *improve value delivery and value proposition*, what are your *key decision drivers* in the dilema whether you will *push your external partners* to bear the cost to redesign part of their data capture and exchange processes or you will do so?
Q26	"We are interested in enhancing our partner's networkability and data sharing capabilities even if that means that we will both take actions that include to mutually share more data between us, than regulatory compliance imposes".To what degree does that statement apply in your company for the partners listed below ?

Apdx Table 1: Open ended questions for multiple case study research interviews (mRQ1)

Interview variables:
Trust about: Data ownership, data management, data openness
Ecosystem Actor Relationship Dynamics: actor interdependence, actor position/power, actor relationships
Ecosystem expansion: number of actors, incentive to participate, network effects

Interview dimensions:
Inbound sc partners*: (i) 1st tier mat. Suppliers, ((ii)2nd+ tier material suppliers,
(iii) inbound Logistic Service Providers (LSP)
* Focus on matterial suppliers as more critical than LSP in manufacturing supply chain a and due to the need to monitor external manufacturing outsourcing
Outbound sc partners: (i) market channel intermediaries, ((ii) outbound lsp
Customers:
Other ecosystem actors: investors, regulatory bodies, institutions

Business Model Dimensions :
Value Creation (Vcr), Value Network (Vntw), Value Proposition (Vpr), value Capture (Vca)

Interview Variables	Supply Chain Dimensions	Interview Question nr
Trust variables, sources of trust	inbound, outbound	Q1
Trust through DLT , actor role , DLT business ecosystem actor relationships change	inbound, outbound	Q6,Q7
Trust variables, actor roles, DLT business ecosystem actor relationships creation	inbound, outbound	Q2,Q3
Trust through DLT, Business Model Value	inbound (material suppliers)	Q11
Trust through DLT, Business Model Value	inbound, outbound (LSP)	Q12
Trust at ecosystem level ,DLT business ecosystem actor relationships creation	inbound, outbound	Q13
Relationship change shock	inbound, outbound	Q10
Trust variables,sources of trust, rebuild DLT business ecosystem actor relationships	inbound, outbound	Q4,Q5
Sources of trust ,actor role, risk of collaborating with competitors or co-opetitors	inbound, outbound	Q17
Business ecosystem actor position/power, level of trust	inbound, outbound	Q25
Data openness, Value proposition	all	Q14
Data openness risk	all	Q15
Data openness, Value proposition, Risk emerged by actor relationship dynamics	inbound, outbound	Q18
Business ecosystem actor role, lelvel of trust	inbound, outbound	Q23,Q24
Low trust level, sources of trust	ecosystem	Q19
Mistrust, sources of trust	inbound, outbound, ecosystem	Q8
New market/white space opportunities , business ecosystem actor role	all	Q20
Data openness, trust variables , network effects	inbound, outbound, ecosystem	Q21
Data openness, ecosystem expansion	inbound, outbound, ecosystem	Q22
Data openness for niche ecosystem actors	all	Q16
competence vs integrity (trust organisation model dimensions)	inbound, outbound, ecosystem	Q9
Data openness intnention (apart from regulatory body legislation)	inbound, outbound	Q26

Apdx Table 2: Multi case-study research interview design (mRQ1)

Interview Question	B.M. dimensions 4V BM	Supply Chain dimensions	1st order Concepts
Q2,Q3	Vcr	inbound, outbound	For key LSPs and material providers trust based on data openness is a significant partnership decision maker
	Vcr	inbound, outbound	For non-key supply chain partners trust based on data openness is not a significant partnership decision maker, appart from non key outbound LSPs that it weighs a bit more but still does not
	Vcr	inbound, outbound	For both key and non-key market intermediaries trust based on data openness is not significant partnership decision maker
Q1	Vcr	inbound, outbound	Assess how complete are **potential** supply chain inbound and outbound partner's data
Q1	Vcr	inbound, outbound	Assess **potential** supply chain inbound and outbound partner's compliance with quality and SLA specifications
Q1	Vcr	inbound, outbound	Assess **potential** supply chain inbound and outbound partner's technical capabilities
Q9	Vcr, Vca	inbound, outbound, ecosystem	We prefer our partners to demonstrate competence vs integrity if we had to choose between those two trust variables
	Vcr, Vca	inbound, outbound, ecosystem	We believe we can manage integrity with strict rules and visibility but for competence this is not the case
Q13	Vcr, Vntw	inbound, outbound	Near real time' visibility into 2nd tier material suppliers affect organization's propensity to trust its respective 1st tier material suppliers
	Vcr, Vntw	inbound, outbound	Near real time' visibility into 2nd tier LSP trust affect organization's propensity to trust its resepctive 1st tier LSPs
Q11	Vcr, Vca	inbound	Near real time' visibility into 2nd tier material suppliers trusted data enhances organization's cost structure capabilities .
	Vcr, Vca	inbound	Near real time' visibility into 2nd tier material suppliers trusted data affects organization's flexibility to mitigate risks.
Q12	Vcr, Vca	inbound, outbound	Near real time' visibility into 2nd tier LSP trusted data strengthens organization's faith on 1st tier partner integrity and performance.
Q6,Q7	Vcr, Vntw	inbound, outbound	Both key and non-key 1st and 2nd tier material suppliers are eligible to be substituted if their respective competitors are expected to be trusted more.
	Vcr, Vntw	inbound, outbound	Outbound LSPs are more eligible than inbound LSPs to be substituted by their respective competitors if more trust is promised
	Vcr, Vntw	inbound, outbound	Non key LSPs are not paid much attention on how they perform and how much they are trusted
	Vcr, Vntw	inbound, outbound	Both key and non key market intermediary actors are not highly possible to be substituted by their competitors if the latter promise more trust
Q10	Vntw	inbound, outbound	When relationship shocks occur organizations ensure data leakage protection with stricter rules
Q8	Vntw	inbound, outbound, ecosystem	Partner's actionable willingness to improve would strengthen its relationship with the respective manufacturer
Q25	Vpr	inbound, outbound, ecosystem	System ownership and process design is viewed as the most important factors for engagement in any DLT business ecosystem, rather than who will bear the cost and drive the process redesign
	Vpr	inbound, outbound, ecosystem	Expected benefits beats trust concerns in actors decision to implement changes required by DLT adoption
Q8	Vntw	inbound, outbound, ecosystem	Data visibility allows proactive action that will lift, to a large extent, any doubts about partners' potential suspicious behavior
	Vntw	inbound, outbound, ecosystem	Data openness reduces information asymmetry and facilitates ecosystem actor's performance evaluation based on trusted data
	Vntw	inbound, outbound, ecosystem	Data accuracy and consistency achieved through data openness would be an ideal basis for mutual operations improvement effort to thrive
Q21	Vntw	inbound, outbound, ecosystem	If opening more data is needed to attract more actors to collaborate with, then we need to do it by ensuring data leakage and data management intentions by our potential partners
Q14	Vpr	inbound, outbound, ecosystem, customer	Storng propensity to open more data for the 1st material and inbound LSP partners if it is about value creation improvement
	Vpr	inbound, outbound, ecosystem, customer	Companies are not against but do not see much value of redesigning their processes for the sake of 2nd tier supply chain partners' and other ecosystem actors' efficiency
Q23,Q24	Vntw	inbound, outbound	High trust level will not increase tolerance on SLA deviation above predefined thresholds, irrespective of the partners role and ecosystem position

Apdx Table 3: Business model dimension impact on multiple case study data structure per open ended interview question.

Interview Question	B.M. dimensions 4V BM	Supply Chain dimensions	1st order Concepts
Q16	Vntw	inbound, outbound, ecosystem, customer	High propensity not to open data to other dominant players
Q26	Vcr, Vca	inbound, outbound	Conflict between data openness to supply chain partners for operational purpose and data opened to regulatory bodies
	Vcr, Vca	inbound, outbound	Opening more data than thos required through regulatory obigations reduces flexibility on reactive actions
	Vcr, Vca	inbound, outbound	Open more data to anyone than those required by central authorities will be only on project basis only
Q22	Vntw	inbound, outbound, ecosystem	Data are assets and are not opened unless there is solid reason to do so
	Vntw	inbound, outbound, ecosystem	Ecosystem expansion does not provide by default any measurable benefit to justify data openness
Q17	Vntw	inbound, outbound	Relationships with supply chain partners might be reviewed in the case that a supplier is cooperating with competitors, especialy with 1st tier material suppliers
Q4,Q5	Vcr, Vntw	inbound, outbound	Reassess partners competence to deliver results through trusted evidence, to re-establish trust
	Vcr, Vntw	inbound, outbound	Request for more data openness to re-establish broken relationships
	Vcr, Vntw	inbound, outbound	Assess similarity of companies goals vision and intentions to re-establish relationships
Q18	Vpr	inbound, outbound	Predictability of competitors' behaviour based on social network
Q21	Vntw	inbound, outbound, ecosystem	If data opening is demanded by a candidate partner, then we need to assess partners trustworthiness
Q19	Vpr	ecosystem	Evaluation of partner's integrity on data management based on social network
	Vpr	ecosystem	Data provision, if necessary, in generic form to any untrusted ecosystem important actor
	Vpr	ecosystem	If references from social network leave shadows on partner's data privacy and data management capabilities and intentions ,then that is collaboration show stopper
Q2	Vntw	inbound, outbound, ecosystem	Open more data to expand the partner base if this is expected to bring significantly more benefits than not doing so
Q15,Q18	Vpr	inbound, outbound, ecosystem, customer	Data openness only to 1st tier suplly chain partners even if they have storng capabilities to elaborated on knowledge created through data share
	Vpr	inbound, outbound, ecosystem, customer	Data openness beyond 1st level of supply chain partners is not desired, due to unknown actors capabilite to build on knowledge shared
	Vpr	inbound, outbound	Expected benefits drive data openness and collaboration prospect with competitors
Q20	Vcr, Vpr	inbound, outbound, ecosystem, customer	Open more data to the outbound partners to explore new markets
	Vcr, Vpr	inbound, outbound, ecosystem, customer	Open more data with the 1st tier materela suppliers, if any extra configuration is needed, to take advantage of new market opportunities
	Vcr, Vpr	inbound, outbound, ecosystem, customer	Open more data to customers to explore new market opportunities

Apdx Table 3: (continued) : Business model dimension impact on multiple case study data structure per open ended interview question.

Q1	How possible is any in-house involved party to interpret the events that impact productivity based on his/her perception ?
Q2	To what degree are investment decisions related to your department, driven by inefficiencies revealed in internal audits ?
Q3	How do you manage internal audits ?
Q4	How time consuming are internal audits ?
Q5	How often are temporary inefficiencies reflected in internal audits ?
Q6	How do you share data with partners/vendors ?
Q7	How much do you trust the information exchanged by vendors/partners ?
Q8	How often are SLAs with external service providers violated ?
Q9	How do you share data with other factories/offices in the group ?
Q10	How do you employ asset maintenance ?
Q11	How often do you request cause-efect analysis from external maintence providers for unpredicted equipment errors/misfunctions/damages ?
Q12	How satisfied are you overall with the maintenance processes ?
Q13	What ineficiencies do you recognize in inventory deliveries by external manufturers ?
Q14	How resource consuming is to deliver information for equipment pay-per-use cost calculations ?
Q15	For equipment pay-per-use cost calculation do you rely solely on infromation available on your databses ?
Q16	How resource consuming is to deliver information for contractor's cost calculations ?
Q17	For contractor's cost calculation do you rely solely on infromation available on your databses ?
Q18	To what degree do you have visibility on manufacturing processes applied in external manufactured parts ?
Q19	How much are you involved in external manufacturer compliance with specifications given by your company appart from the initial partner onborarding steps ?
Q20	How time consuming is to perform Quality Control on external manufactured parts ?
Q21	How costly is it to perform Quality Control on external manufactured parts ?
Q22	How often do you share specific production process data with customers ?
Q23	How are audits from external entities employed ? (s-str)
Q24	How resource consuming is to gather data related to production processes in case of claims ?
Q25	How do you record supply chain sustainability factors and metrics ?
Q26	How much do you act upon customer feedback ?
Q27	How is customer feedback communicated internaly ?
Q28	Please name the different connected (online) in company's intranet information systems or databases involved in the production system operation?
Q29	Please name the different stand alone (offline) information systems or databases involved in the production system operation ?
Q30	What intra-company data exchange inefficiences do you recognize ?
Q31	How often data shared with the production system need to be revised ?
Q32	How satisfied are you with the 'near-real-time' information exchange between company departments that intersect to production system operations ?
Q33	What standardized business processes are linked with partners/ vendors with automated data transfer (eg EDI) ?
Q34	To what degree do you consider that more production process integration with parrtners/vendors is needed?

Apdx Table 4: Open ended questions for multiple case study research interviews (mRQ2)

Interview variables:
Data exchange, Real time data access, Data openness, Data capture, Data quality (hidden, ambiguous, incosistent)
Trust
supply chain efficiency
Supply chain process integration
Supply chain data integration

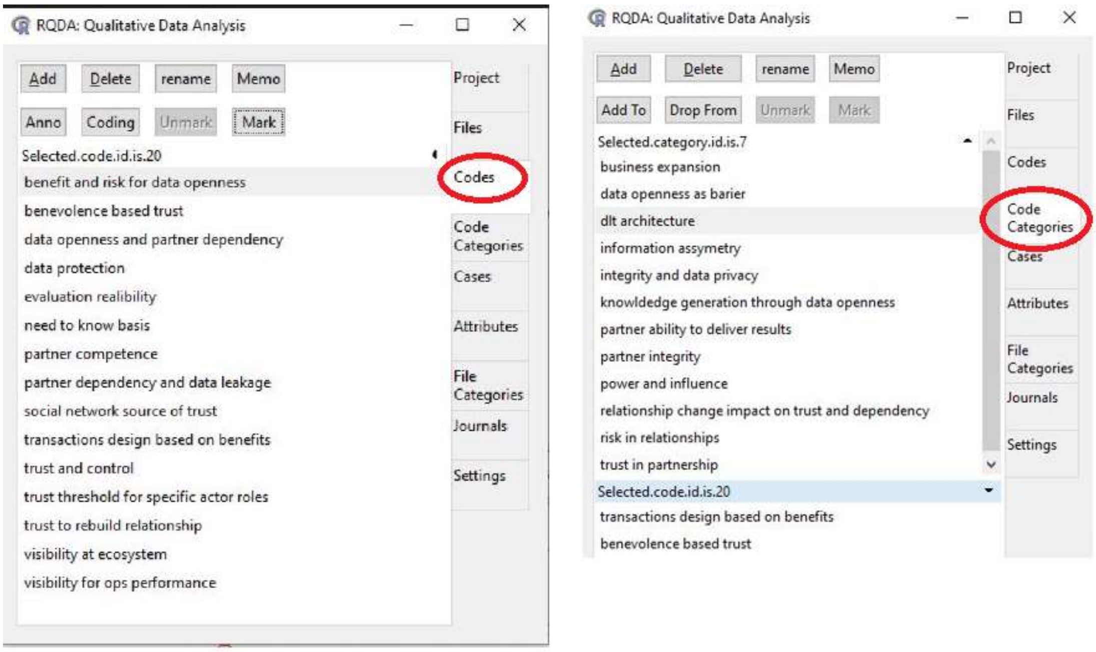
Supply Chain Units of analysis:
In-house (supply chain departments and activities performed internal to the company) that are:
In-house Logistics, Production, Quality Control, Engineering, Maintenance, Inventory management,
Inbound Receipt, Procurement, Production Planning and Control (PPC)

Manufacturer case study selection criteria:
-High level in-house supply chain efficiency effectiveness (based on KPIs)
-High information system integration
-Absence of late configuration manufacturing strategy
-Low level of industry regulation
-Large enterprise (LE)
Group Production Plant section criteria
- Manufacture the same group of products
- Similar production volume
- Top PPC performers (based on the Manufacturing group PPC annual evaluation)

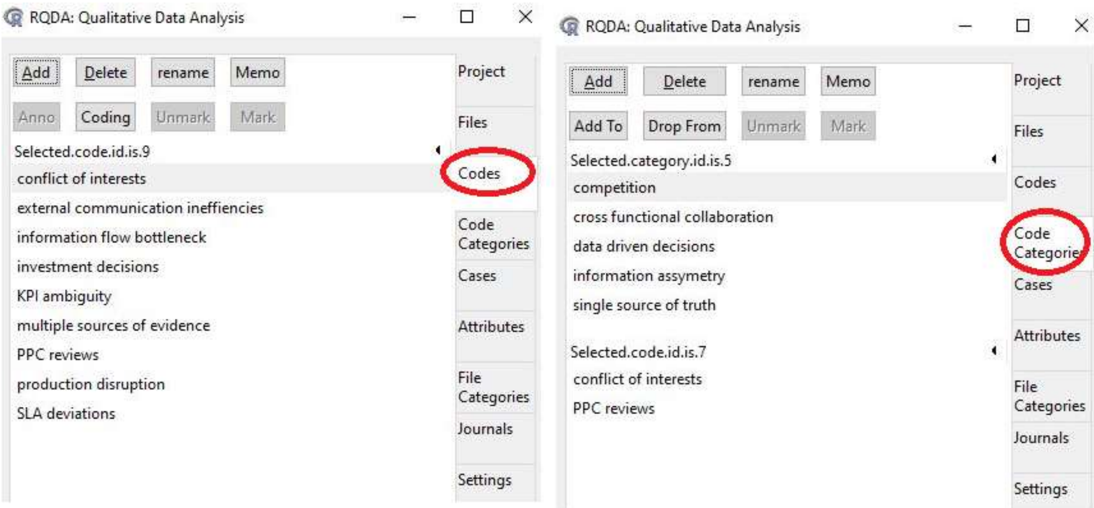
Business Model Dimensions :
Value Creation (Vcr), Value Network (Vntw), Value Proposition (Vpr), Value Capture (Vca)

Interview Variables	Interview Question Nr
real time data access, data capture, data quality	Q1
supply chain efficiency, data capture, data availability	Q2
trust , supply chain efficiency	Q3
data capture	Q4, Q25
supply chain efficiency, data quality,	Q5
data exchange	Q6, Q9
trust, data openness	Q7
trust, supply chain efficiency, data openness	Q8
supply chain efficiency	Q10, Q12, Q13, Q20
trust, supply chain efficiency, data quality	Q11
supply chain efficiency, data capture	Q14
trust, data exchange, data quality, real time data access	Q15
supply chain efficiency, data exchange	Q16
data exchange, data openness	Q17, Q18, Q22
supply chain efficiency, data openness	Q19
supply chain efficiency, data capture	Q21, Q23, Q24
data exchange, real time data access	Q26
data exchange, data openness, real time data access	Q27
Supply chain data integration	Q28, Q29, Q31
Supply chain data integration, data quality	Q30
real time data access	Q32
Supply chain process integration, data exchange	Q33
Supply chain process integration	Q34

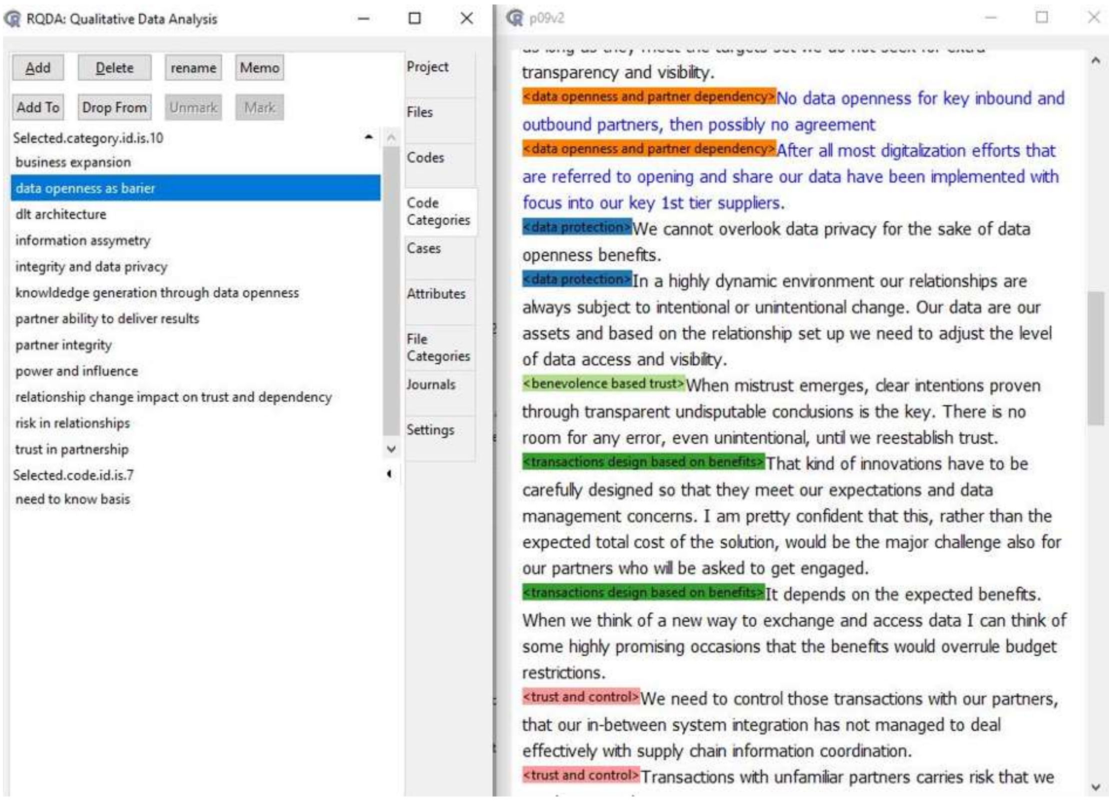
Apdx Table 5: Single case-study research interview design (mRQ2)



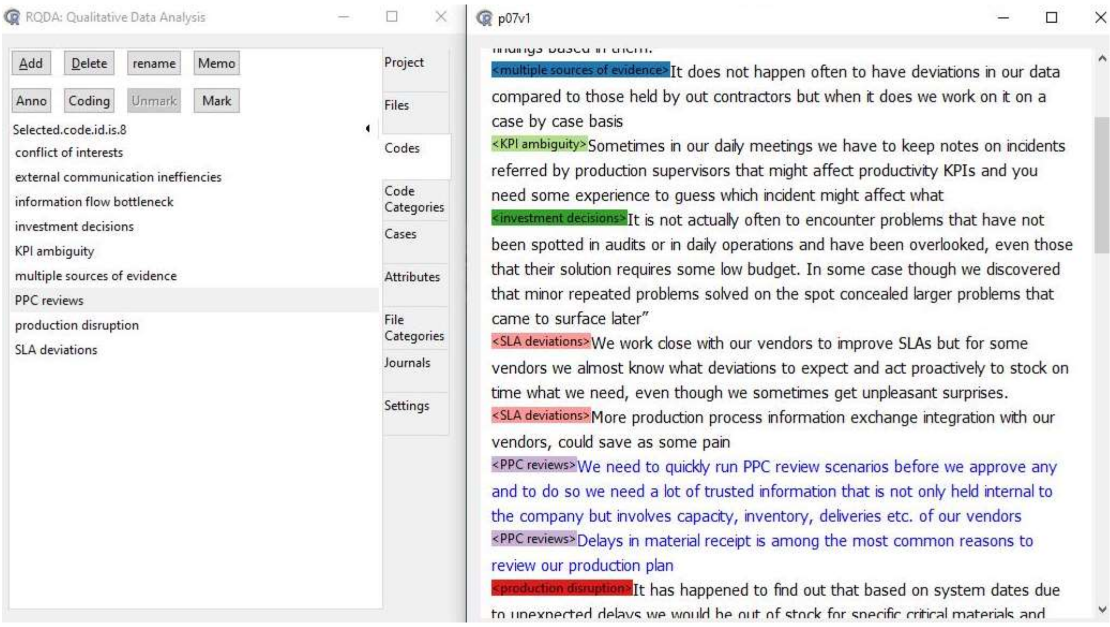
Apdx Figure 1: Code and Code Categories in RQDA for mRQ1 data structure



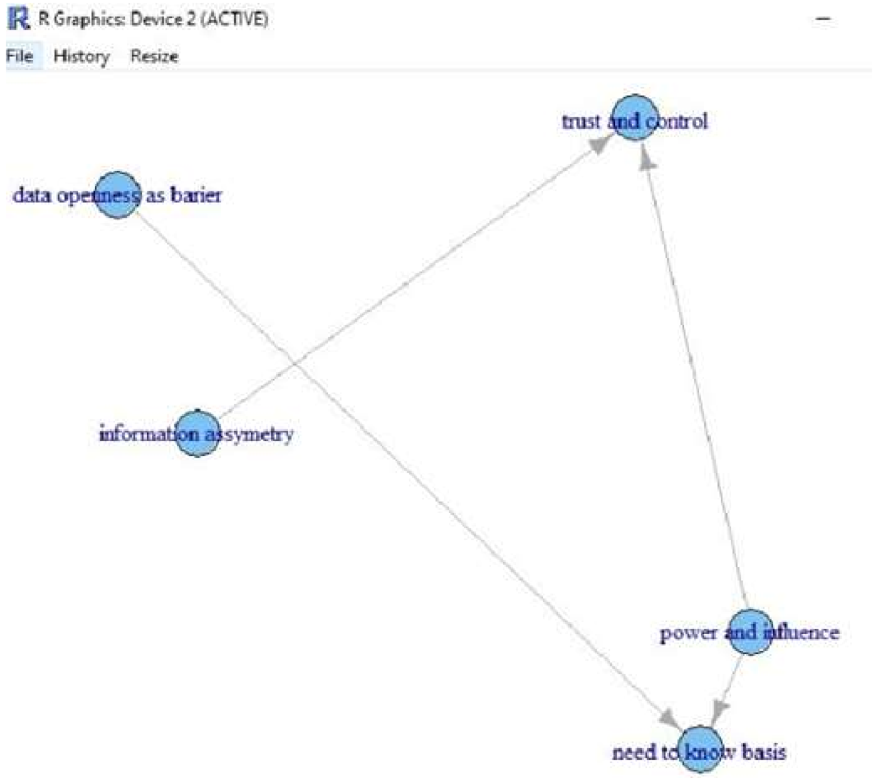
Apdx Figure 2: Code and Code Categories in RQDA for mRQ2 data structure



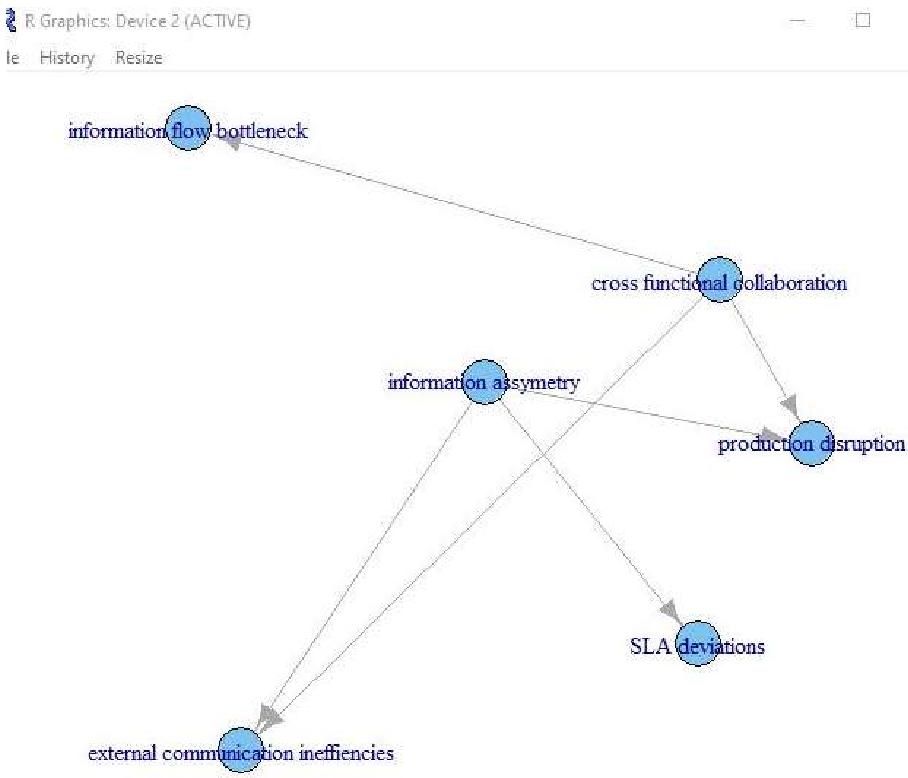
Apdx Figure 3: Coding in RQDA for mRQ1 data structure



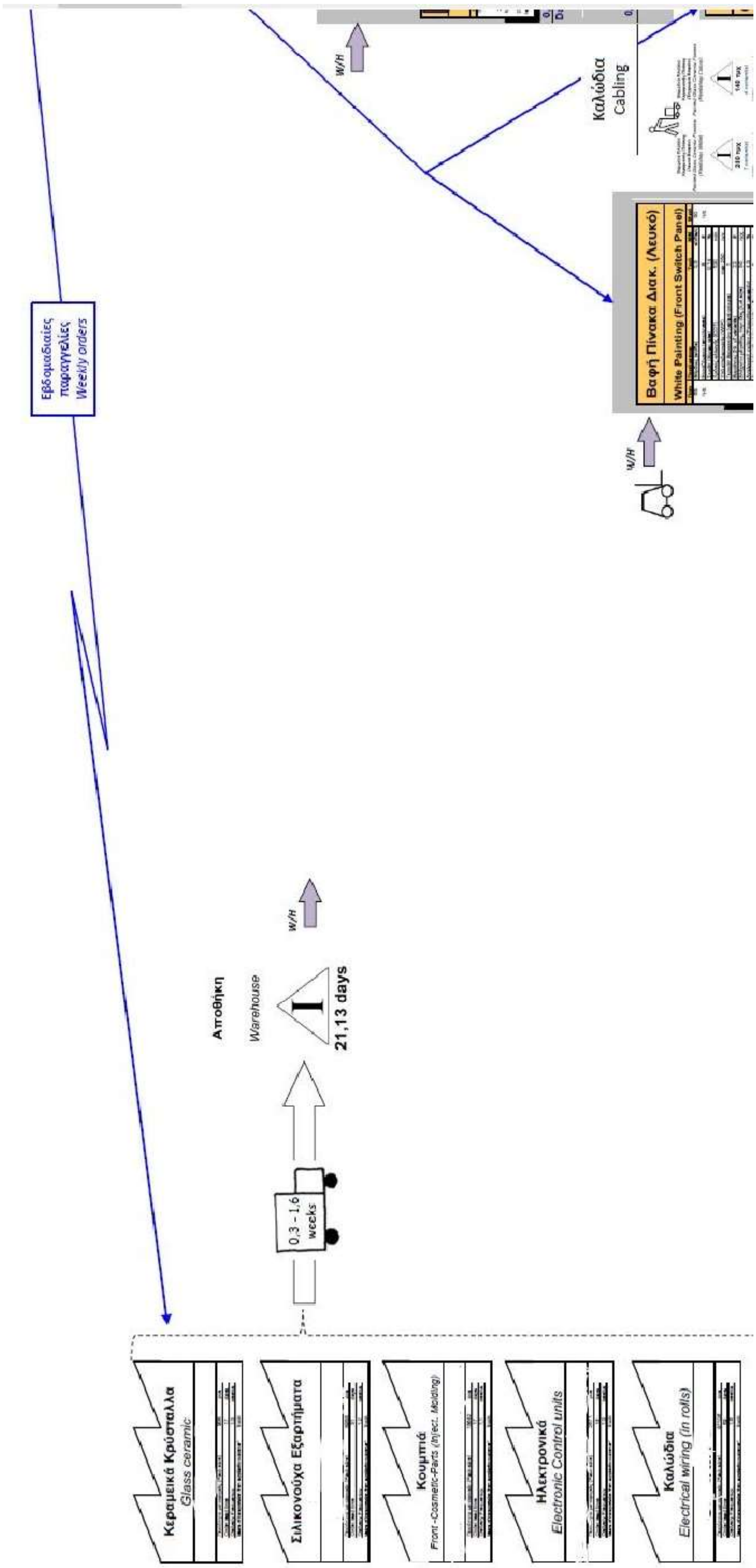
Apdx Figure 4: Coding in RQDA for mRQ2 data structure



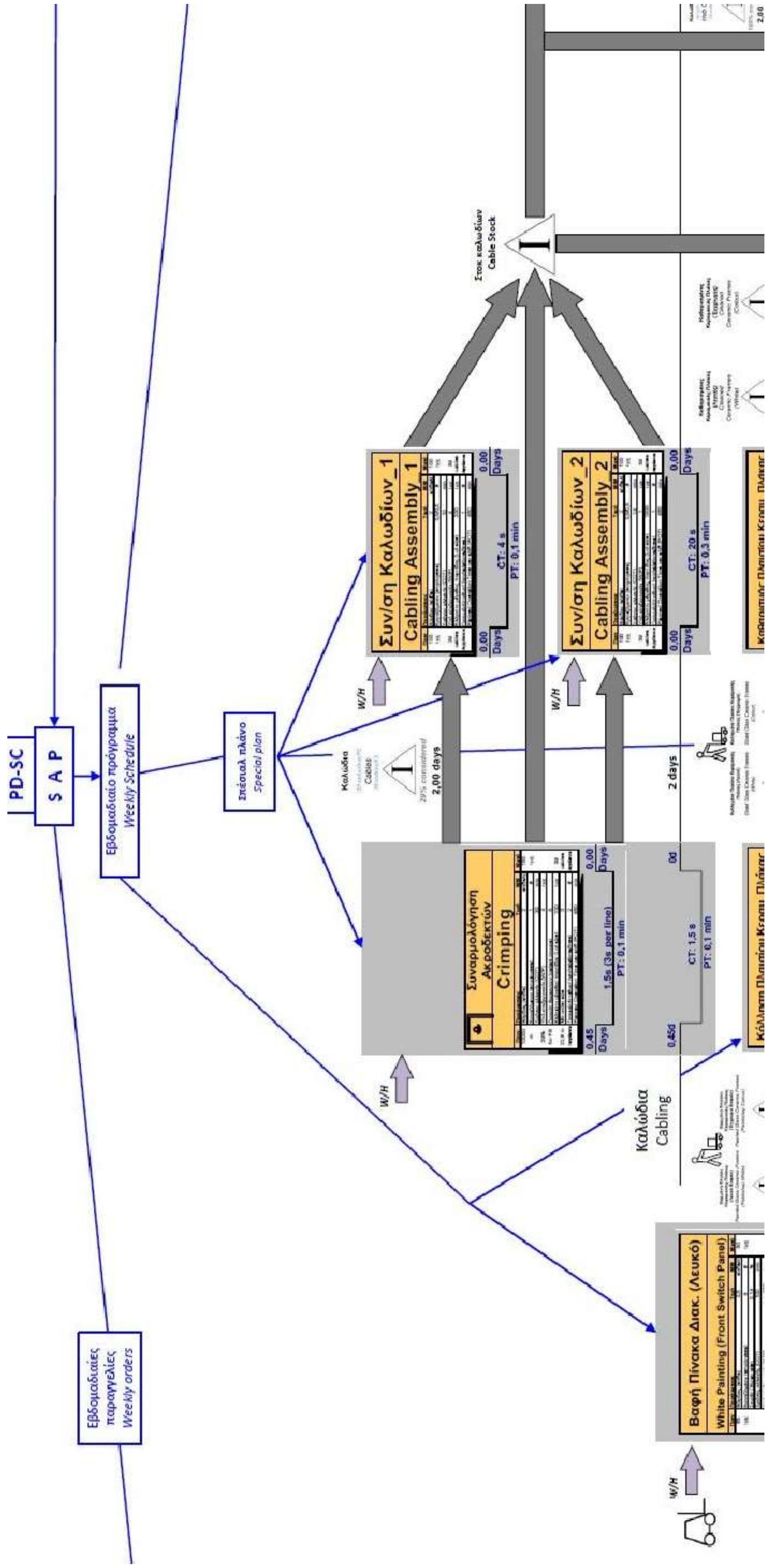
Apdx Figure 5: Coding plotting sample in RQDA for mRQ1 data structure



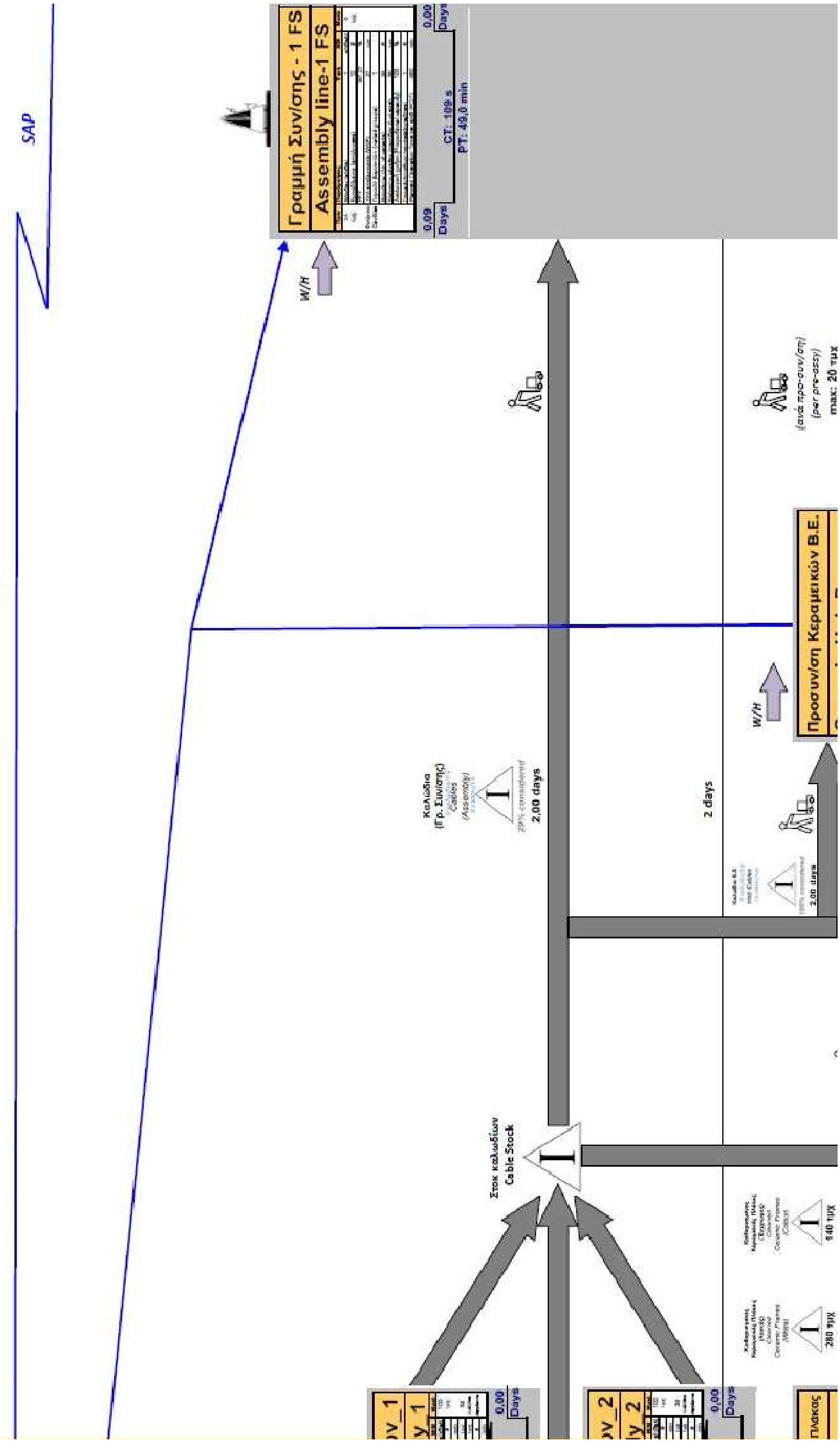
Apdx Figure 6: Coding plotting sample in RQDA for mRQ2 data structure



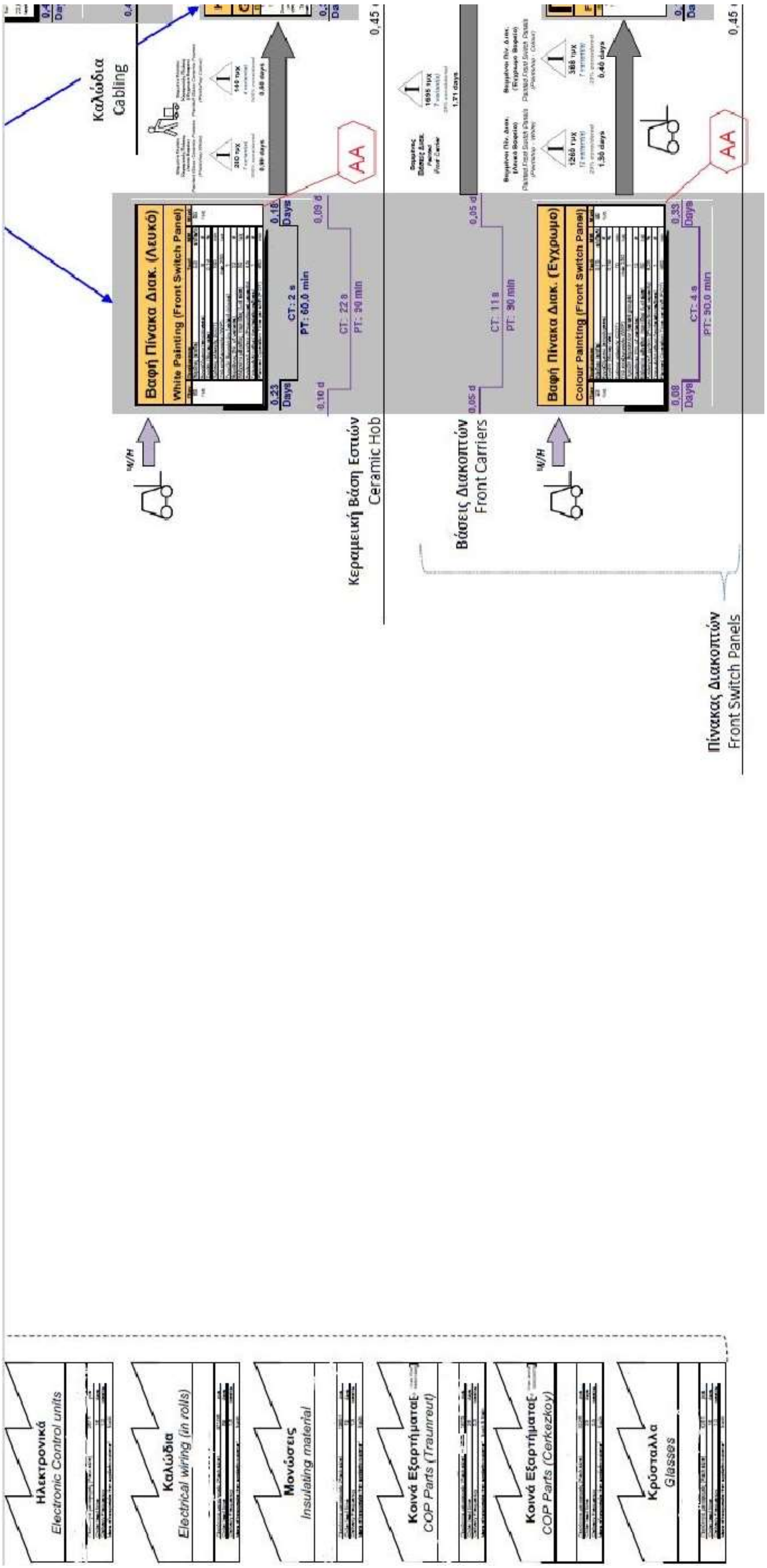
Apdx Figure 7(01): HA-OEM VSM 'as-is'



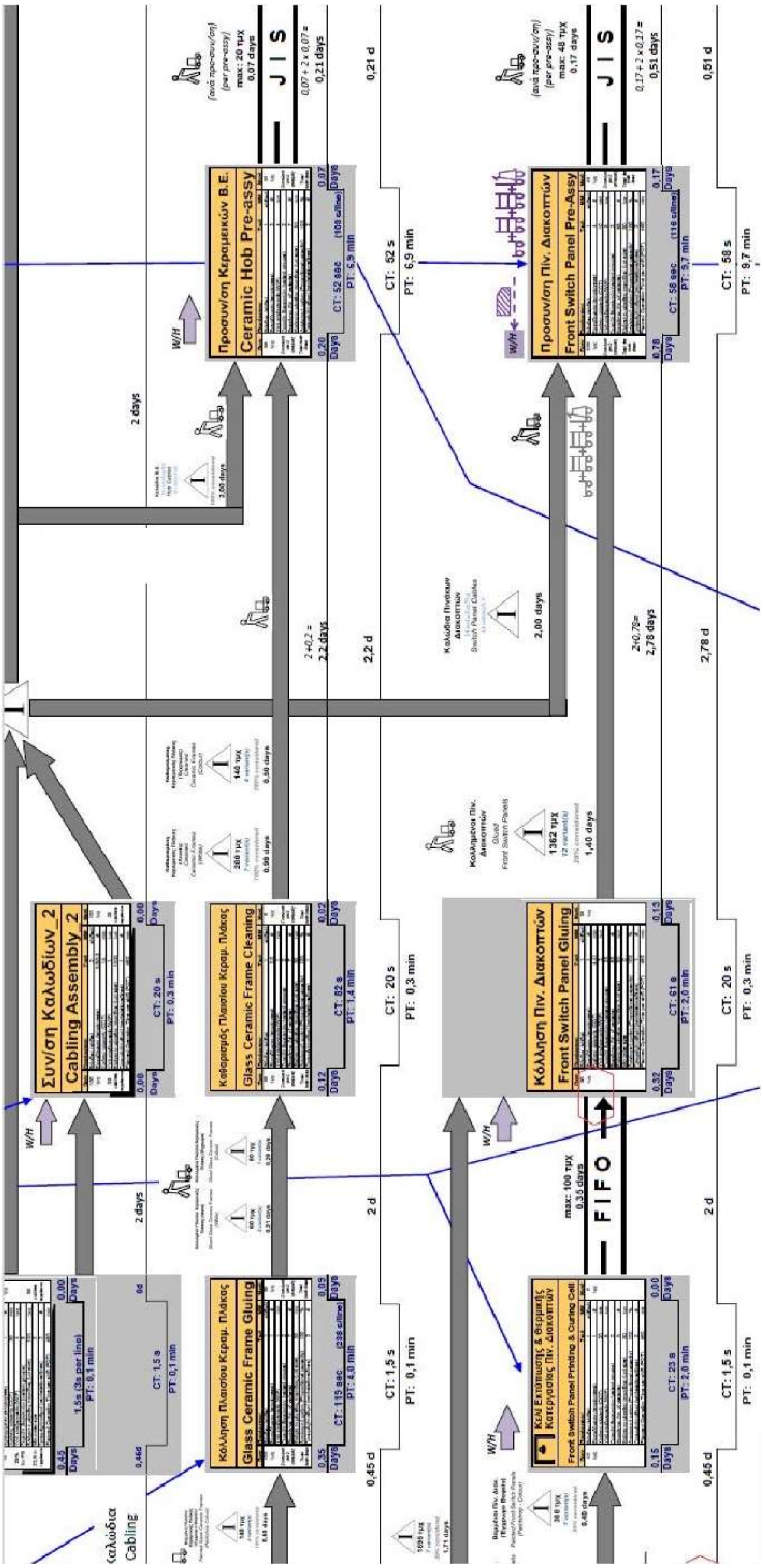
Apdx Figure 7(02): HA-OEM VSM 'as-is'



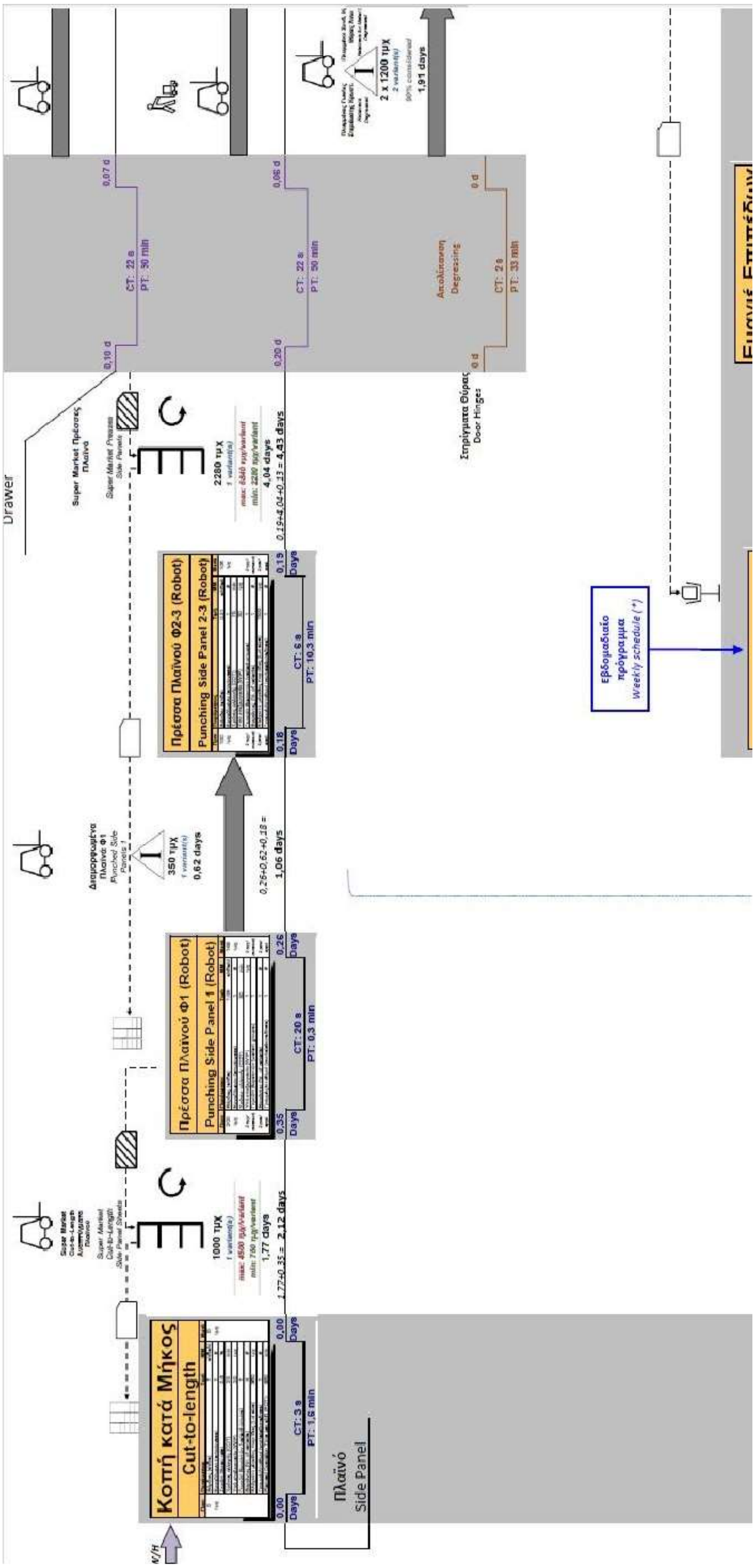
Apdx Figure 7(03): HA-OEM VSM ‘as-is’



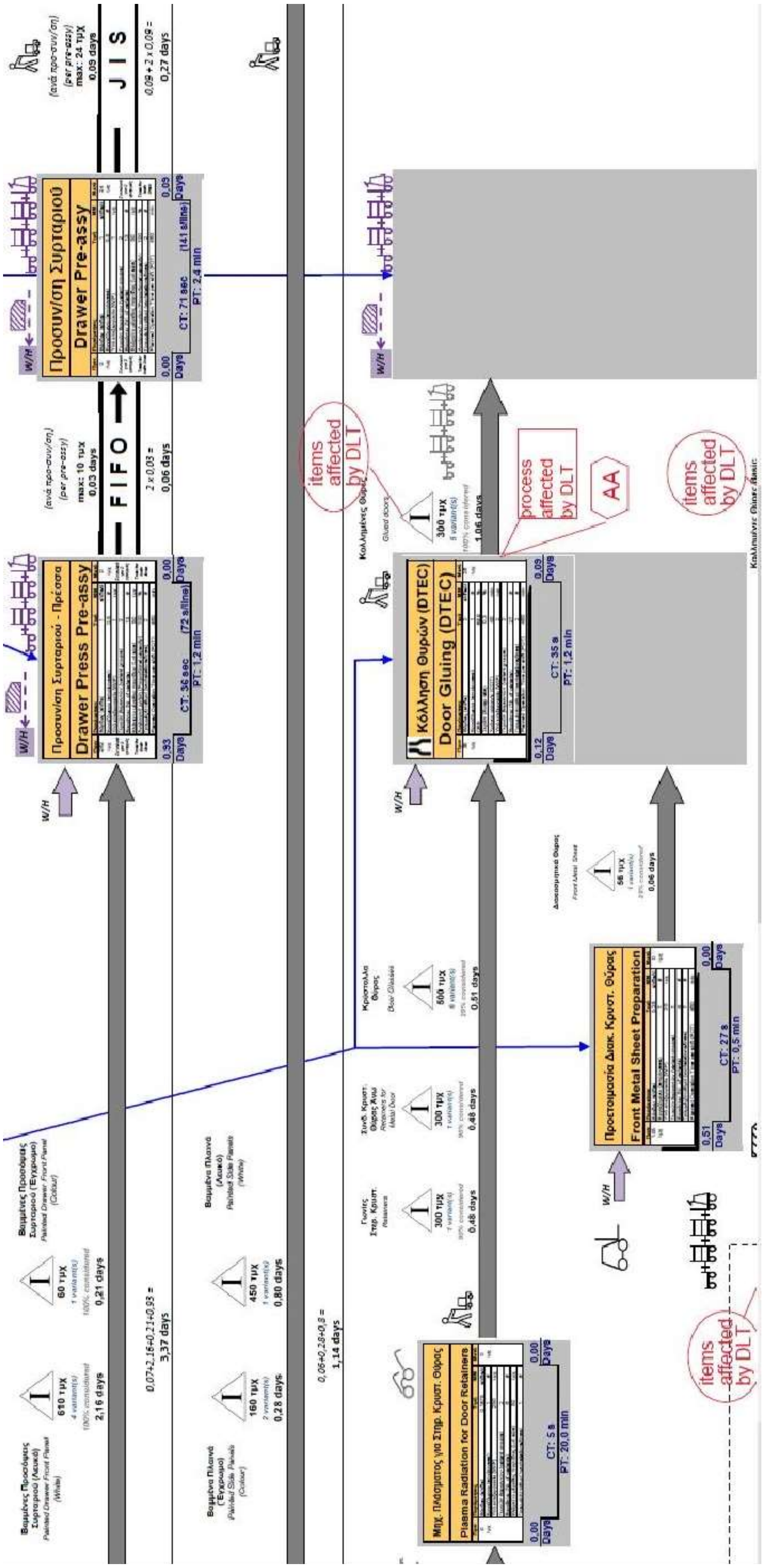
Apdx Figure 7(04): HA-OEM VSM 'as-is'



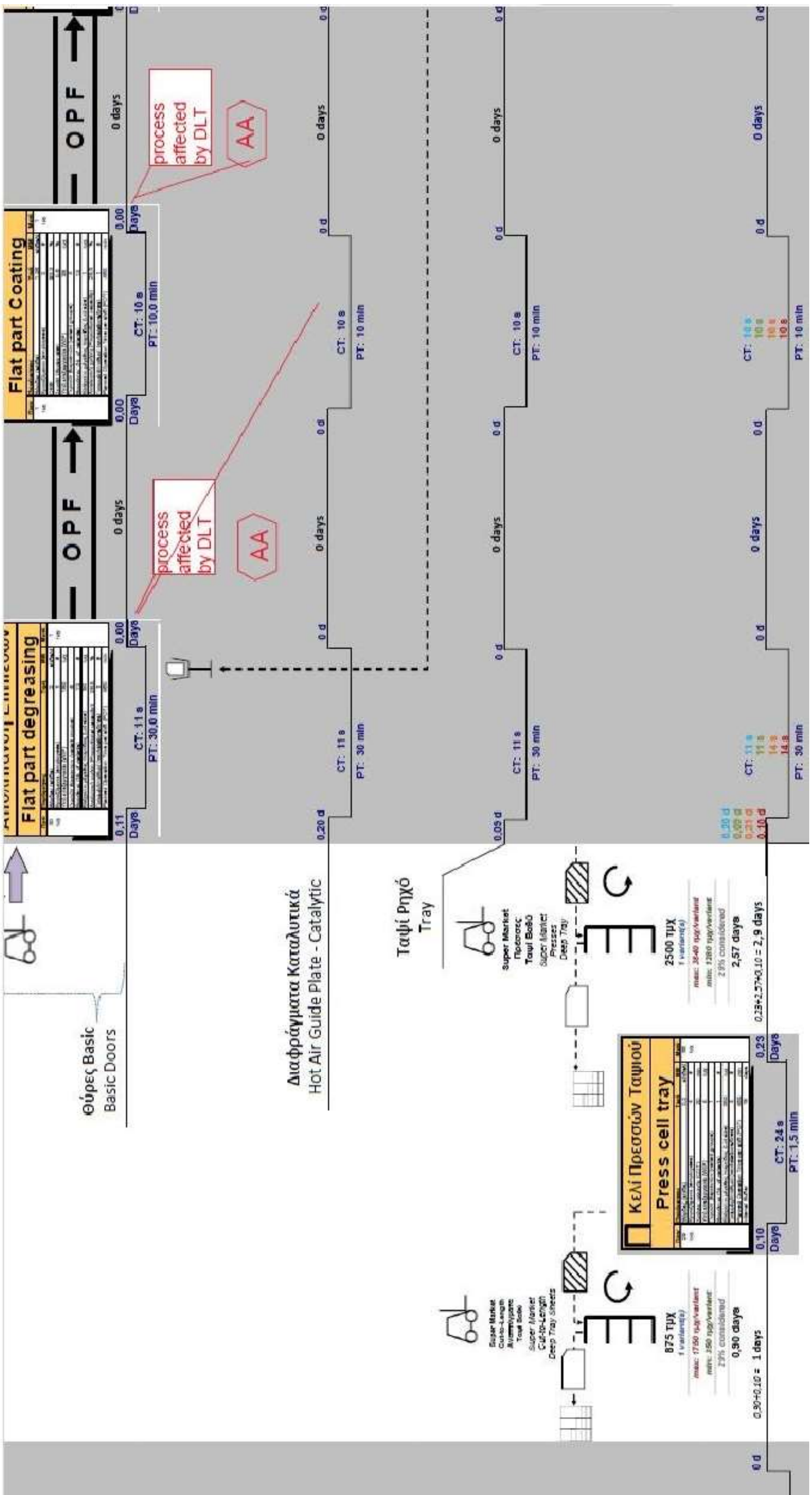
Apdx Figure 7(05): HA-OEM VSM 'as-is'



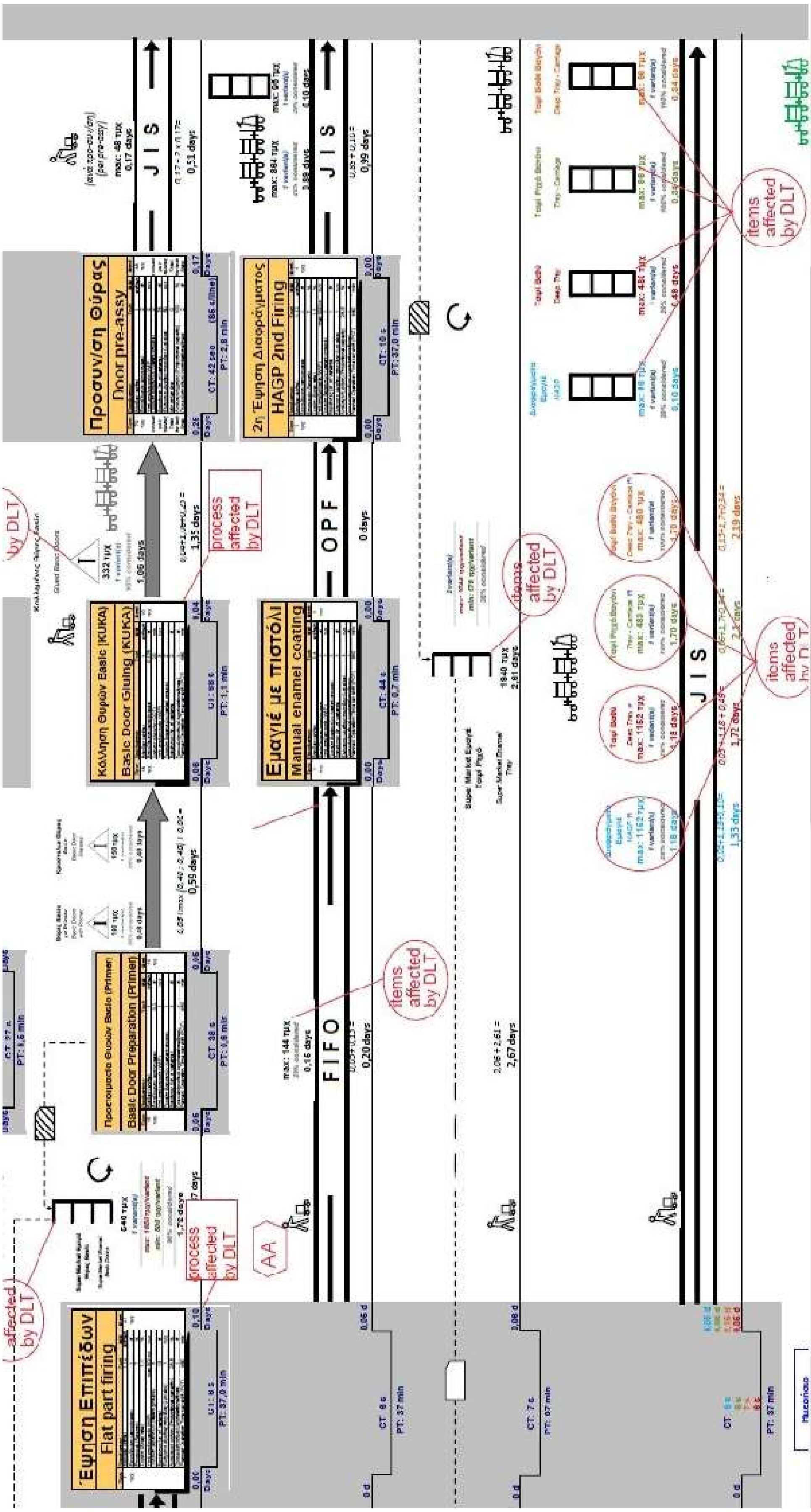
Apdx Figure 7(06): HA-OEM VSM 'as-is'



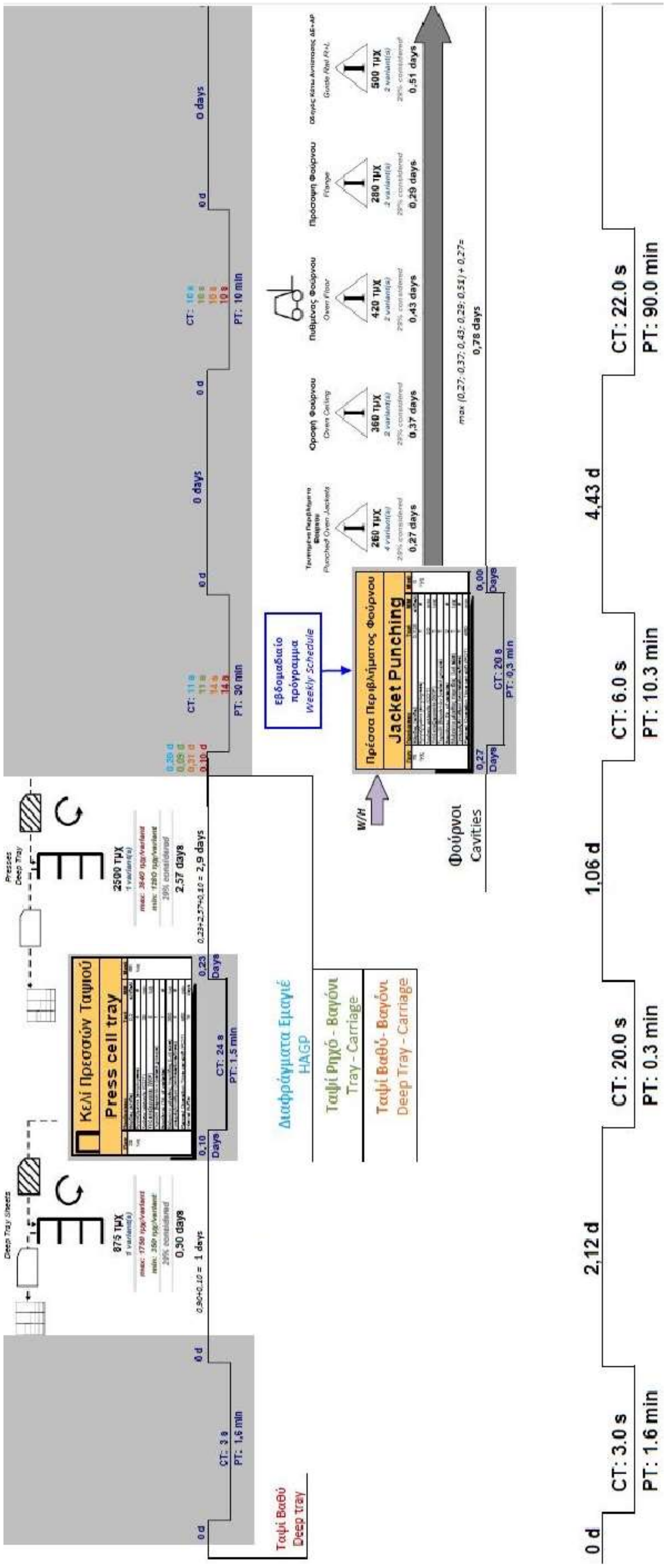
Apdx Figure 7(07): HA-OEM VSM 'as-is'



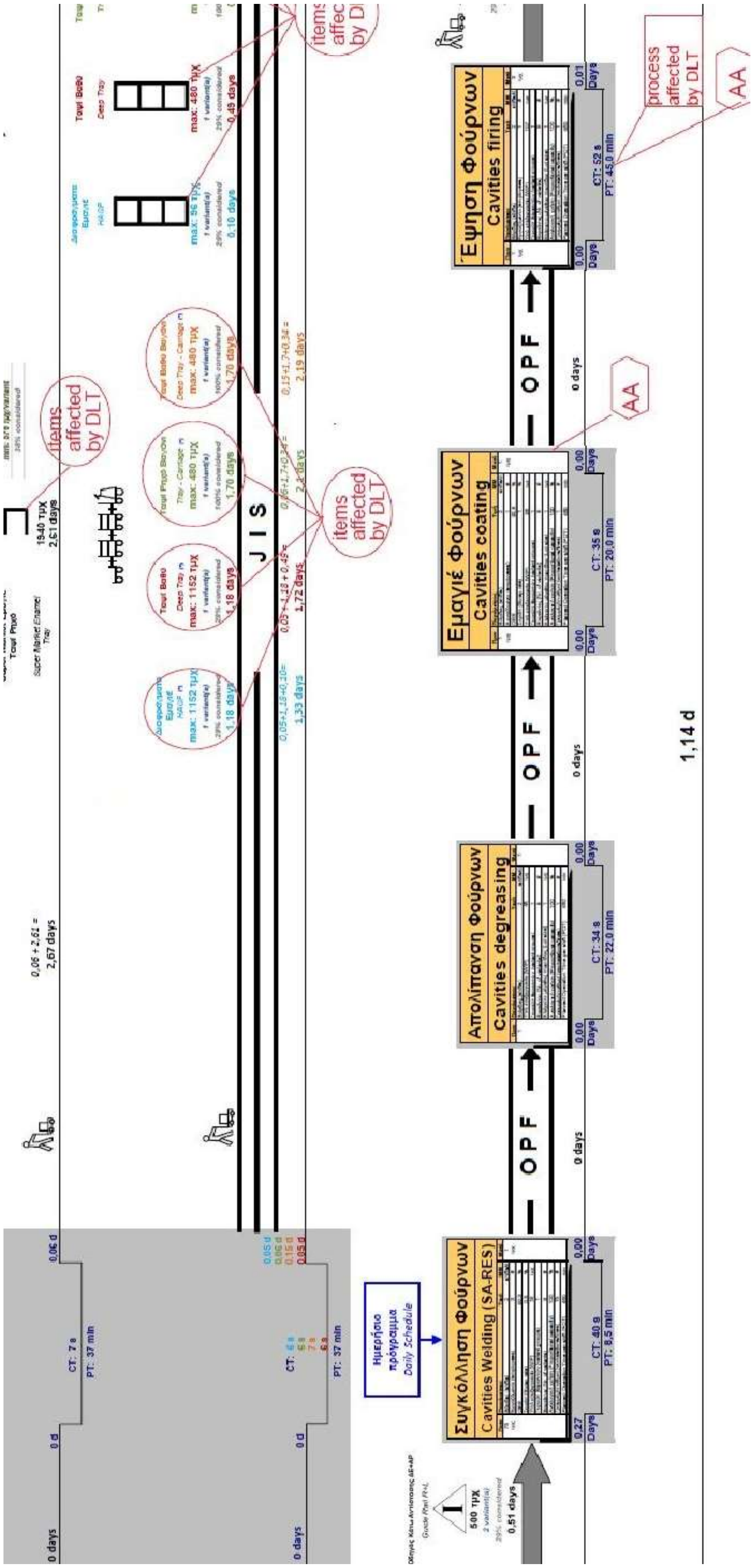
Apdx Figure 7(08): HA-OEM VSM 'as-is'



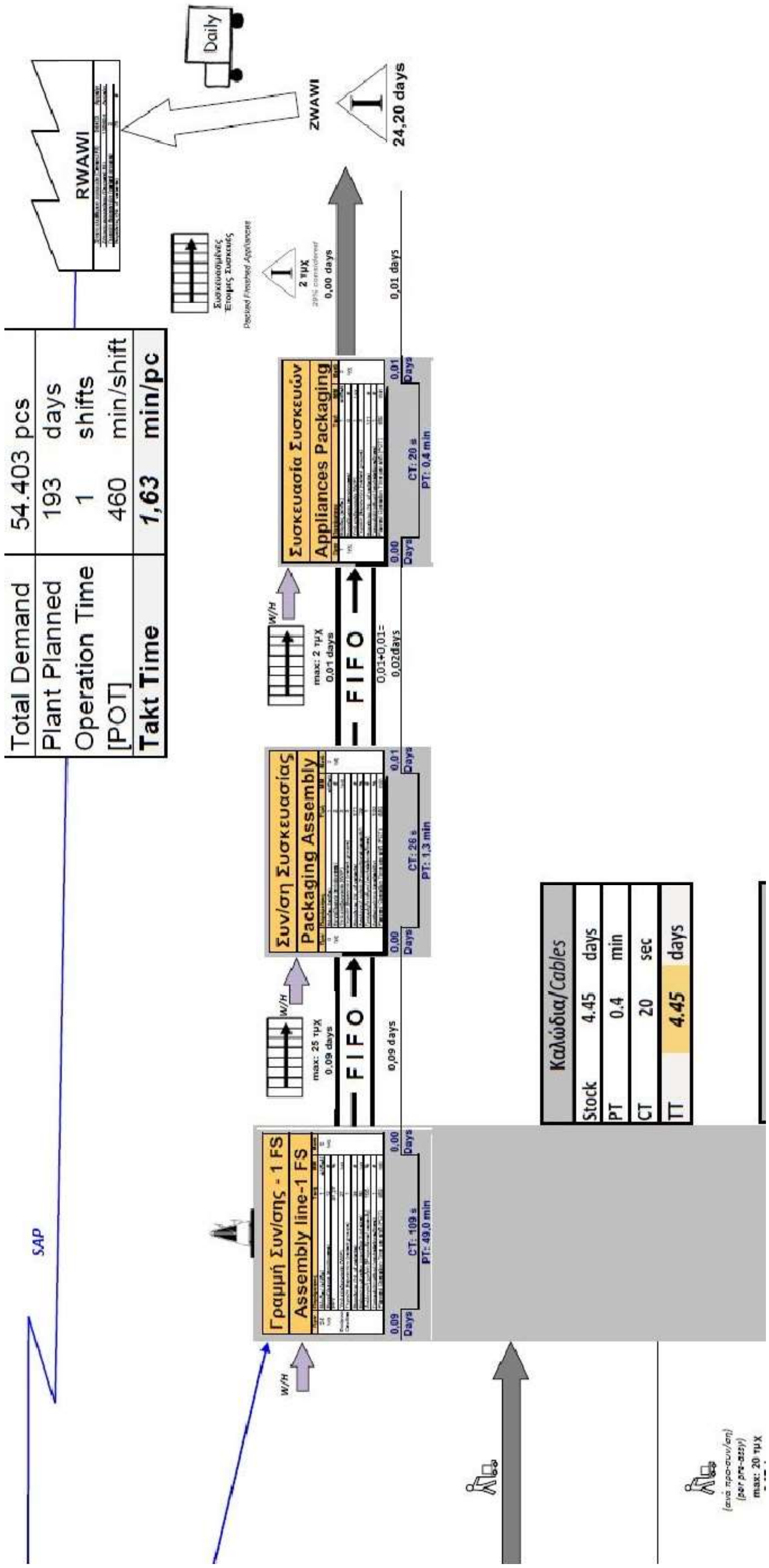
Apdx Figure 7(09): HA-OEM VSM 'as-is'



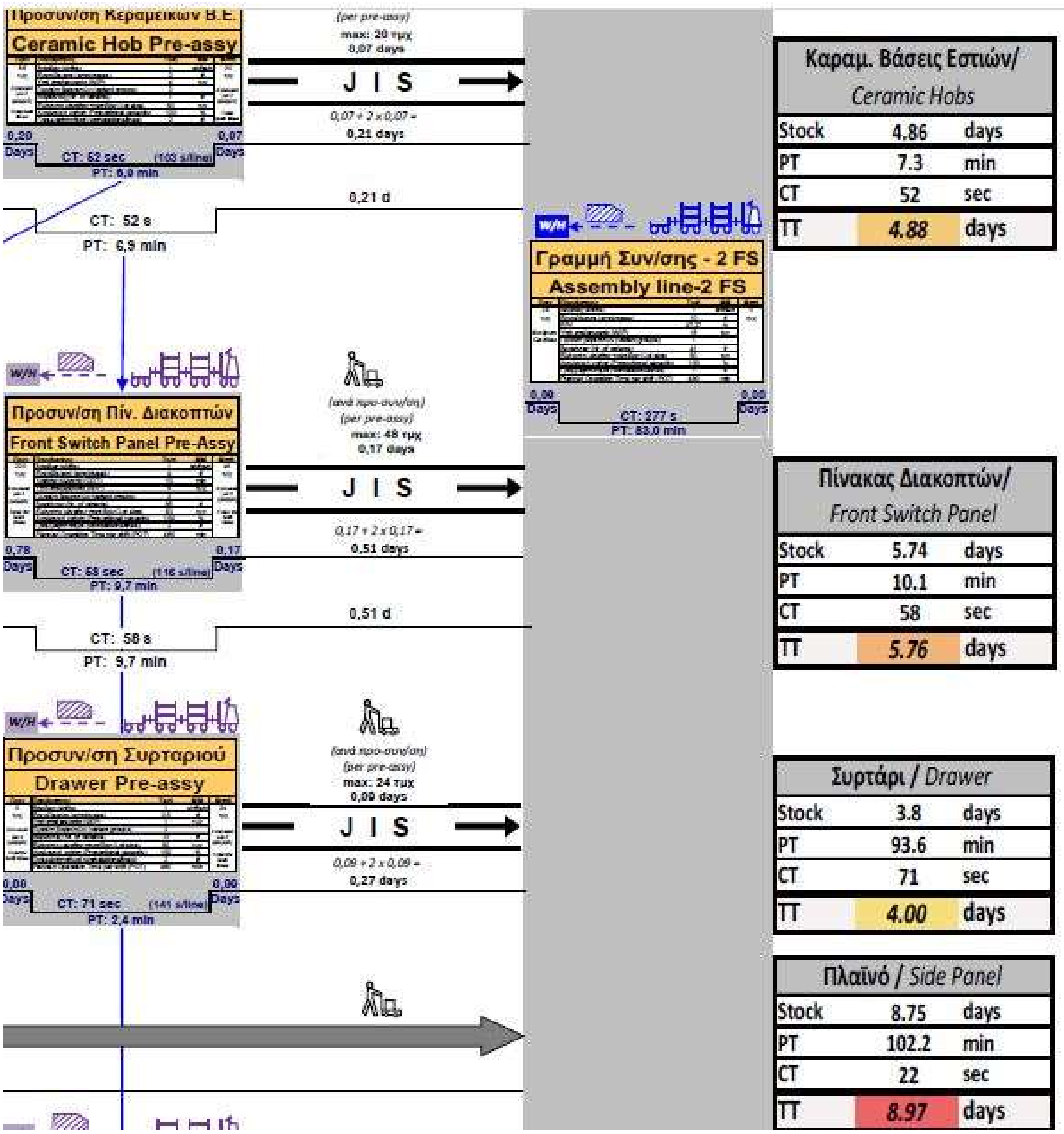
Apdx Figure 7(10): HA-OEM VSM 'as-is'



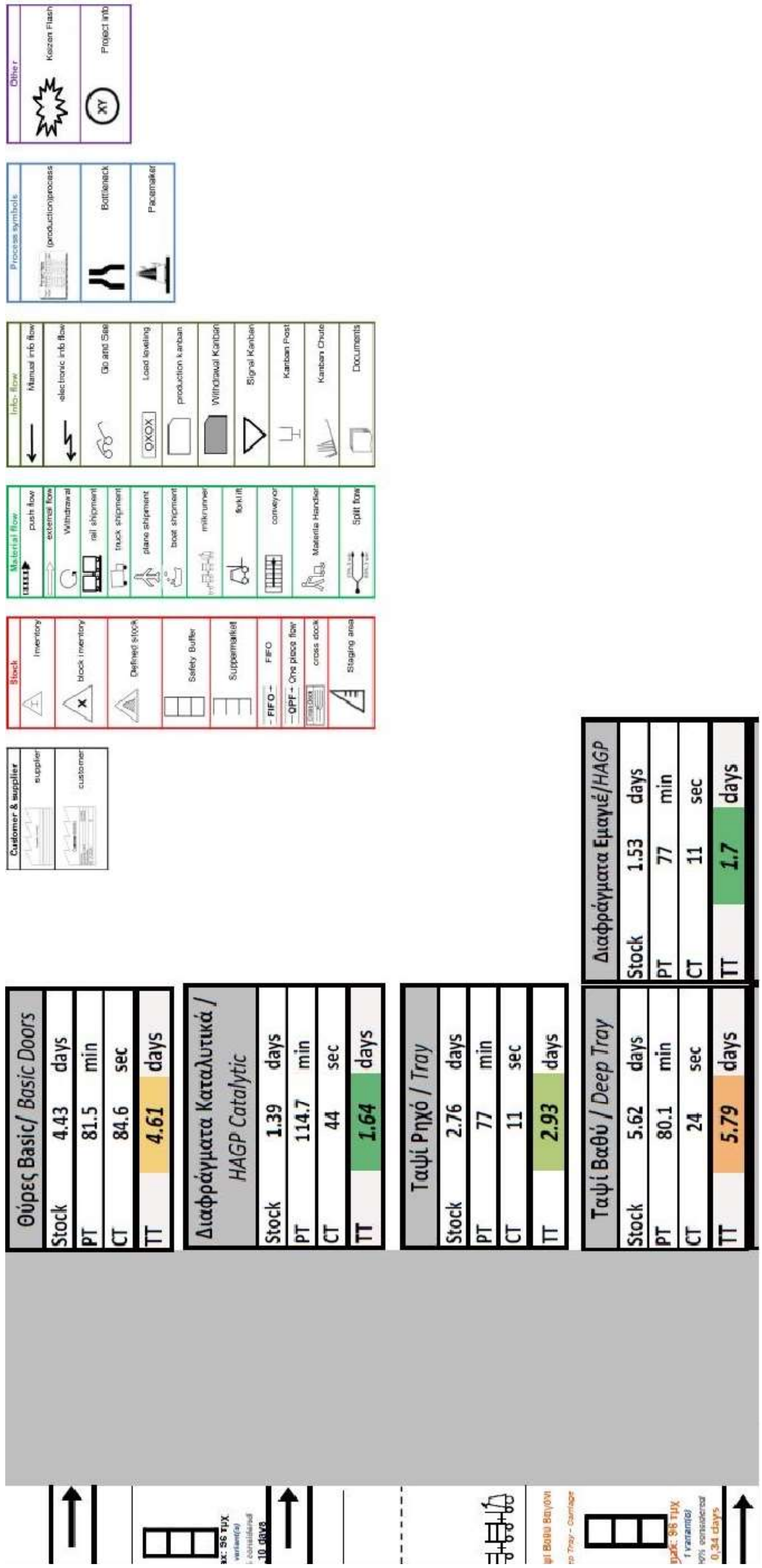
Apdx Figure 7(11): HA-OEM VSM 'as-is'



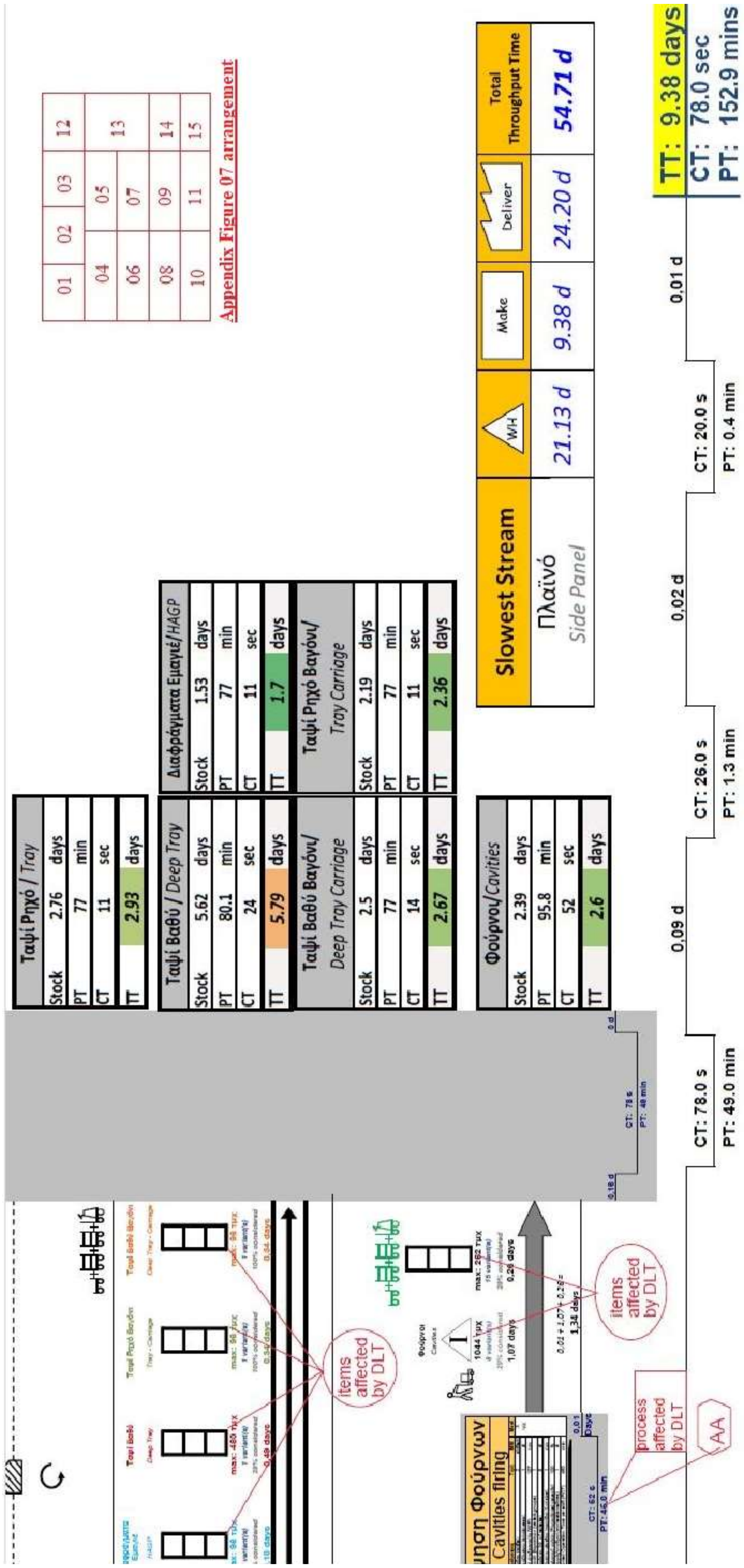
Apdx Figure 7(12): HA-OEM VSM 'as-is'



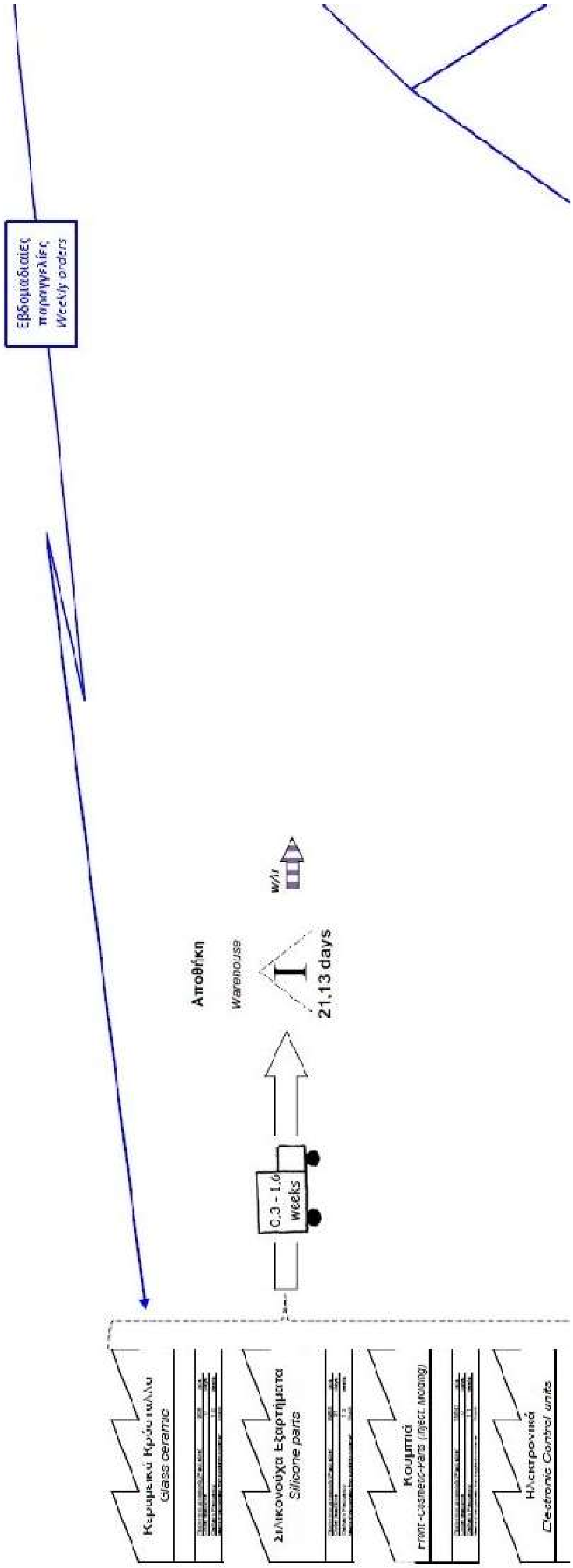
Apdx Figure 7(13): HA-OEM VSM 'as-is'



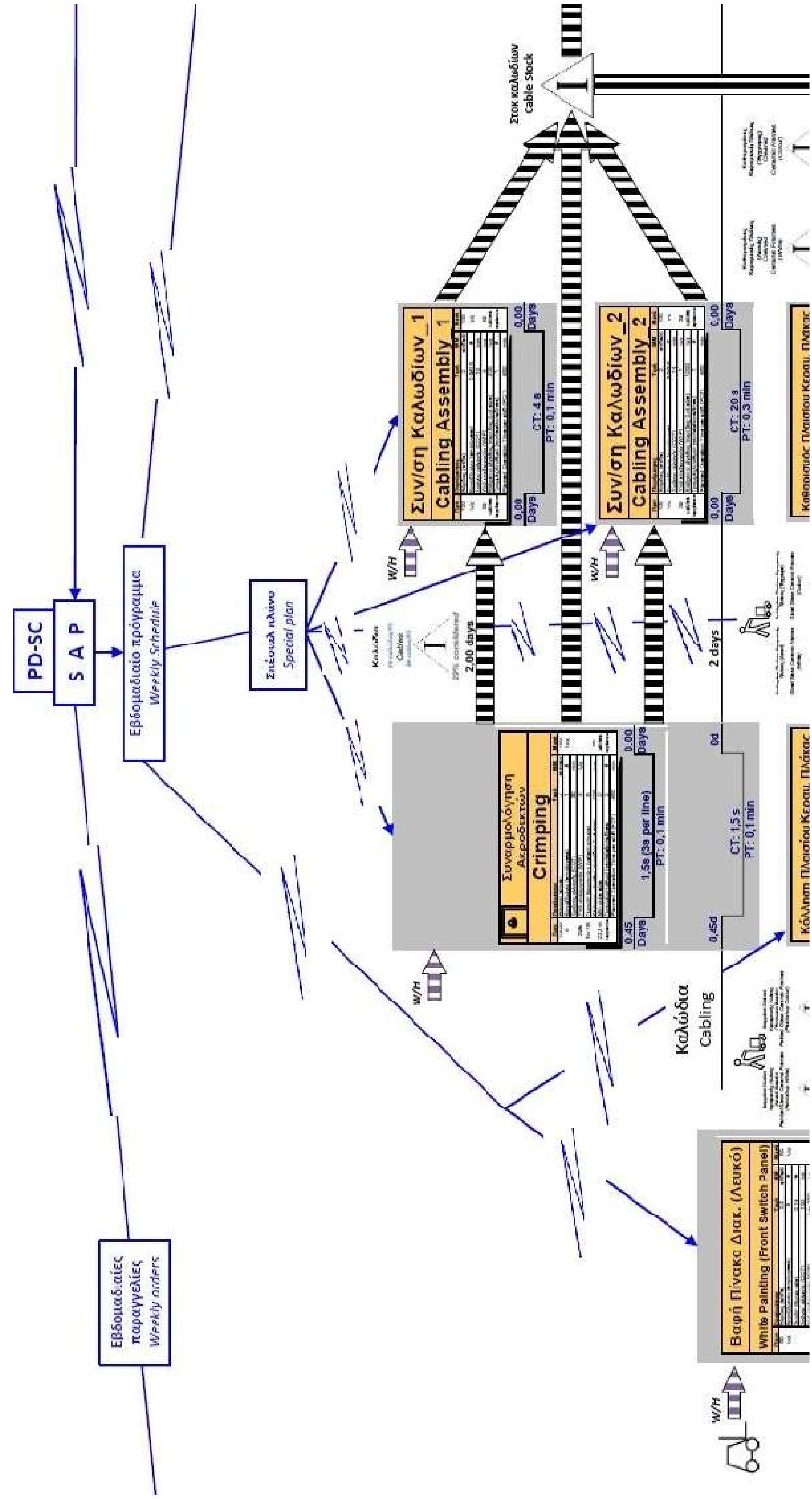
Apdx Figure 7(14): HA-OEM VSM ‘as-is’



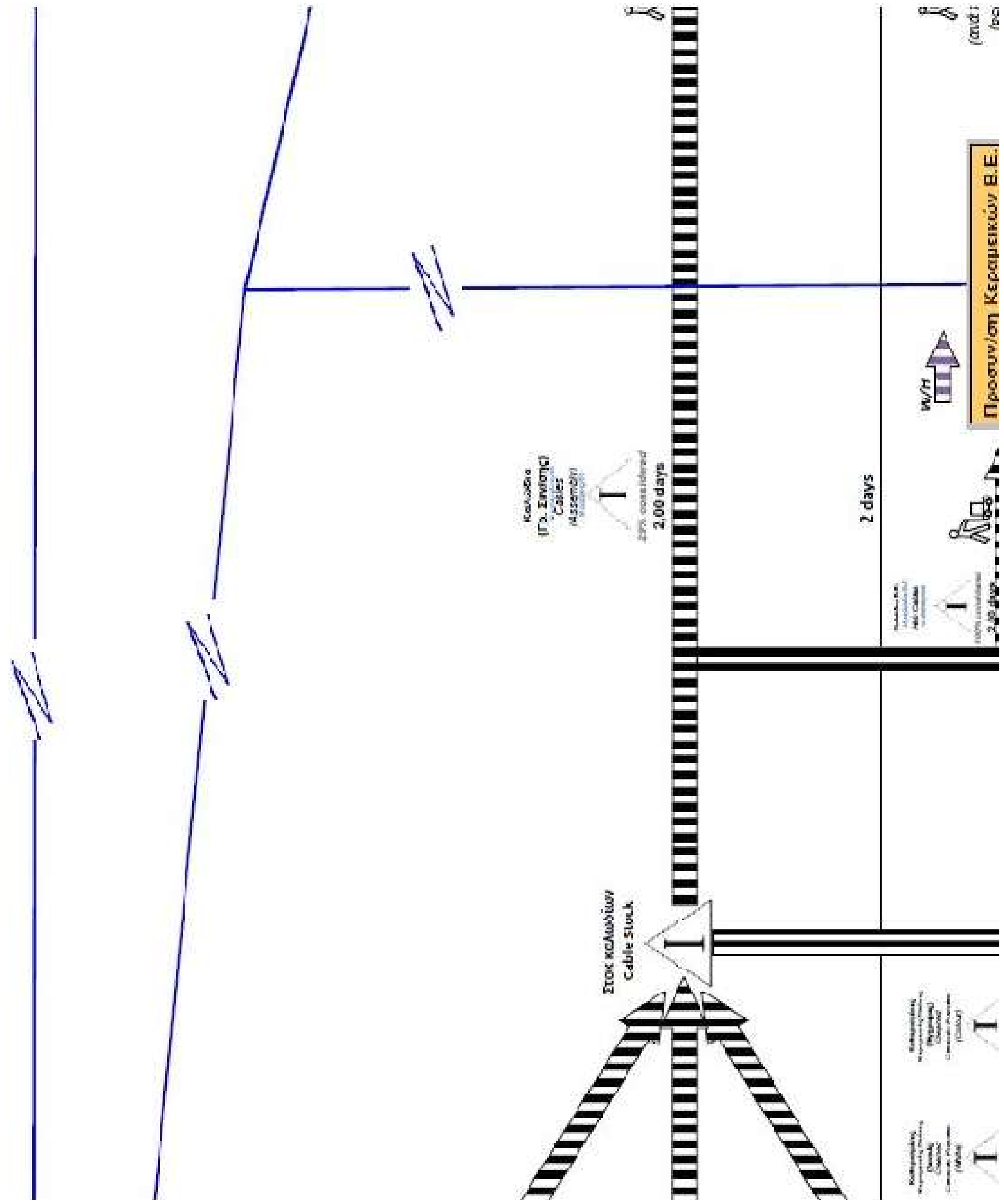
Apdx Figure 7(15): HA-OEM VSM ‘as-is’



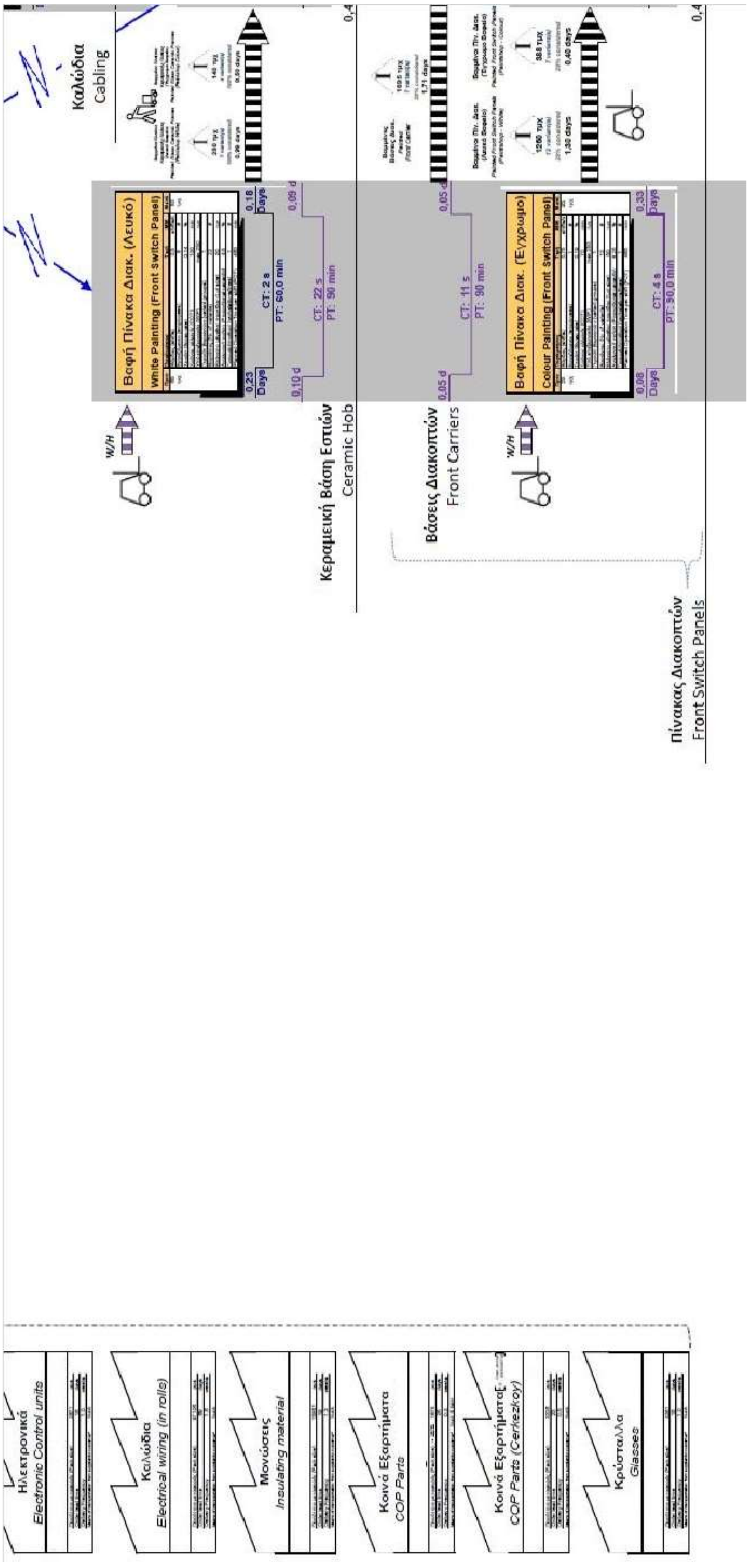
Apdx Figure 8(01): HA-OEM VSM 'to-be' based on DLT scenario



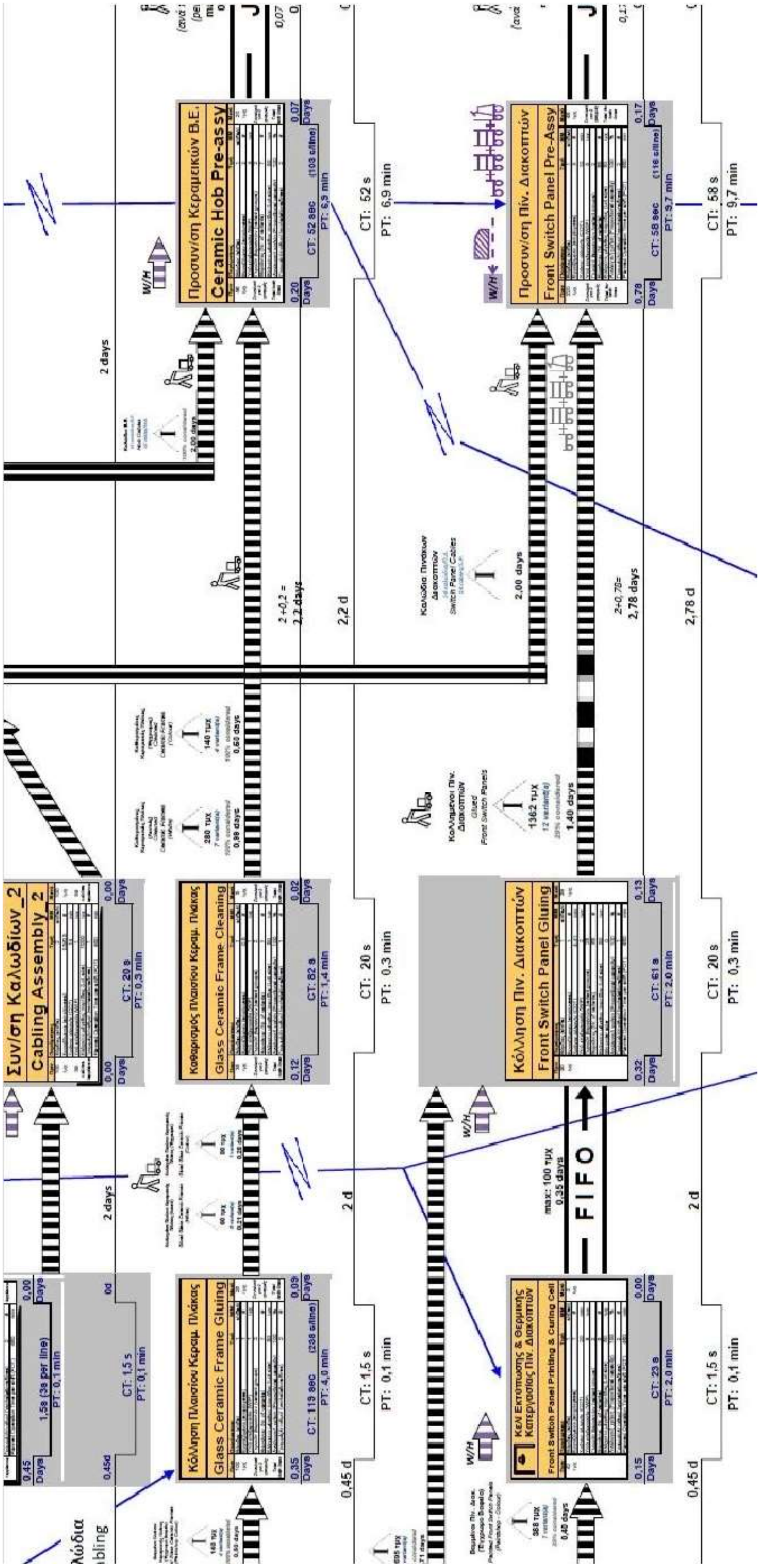
Apdx Figure 8(02): HA-OEM VSM ‘to-be’ based on DLT scenario



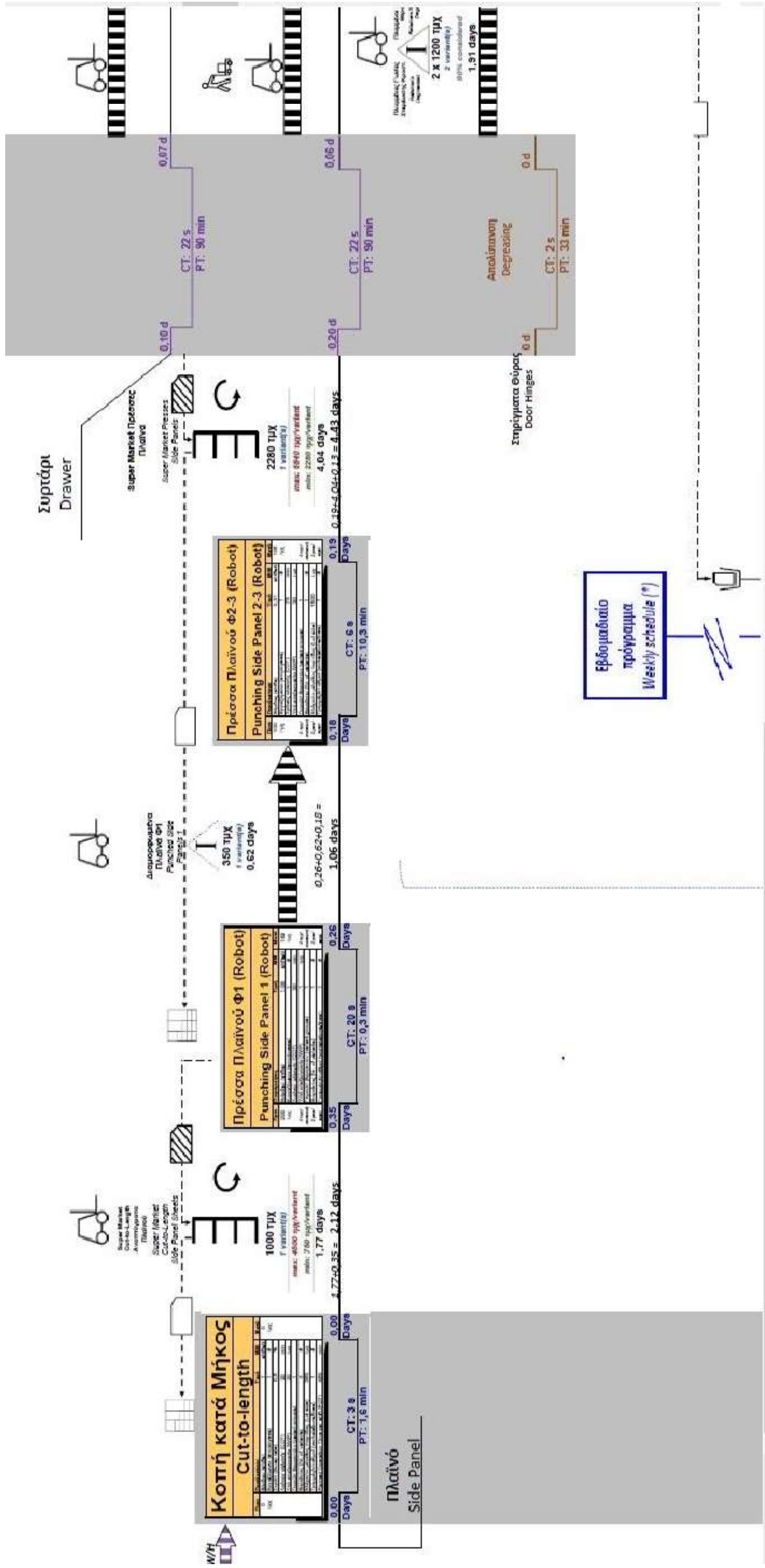
Apdx Figure 8(03): HA-OEM VSM 'to-be' based on DLT scenario



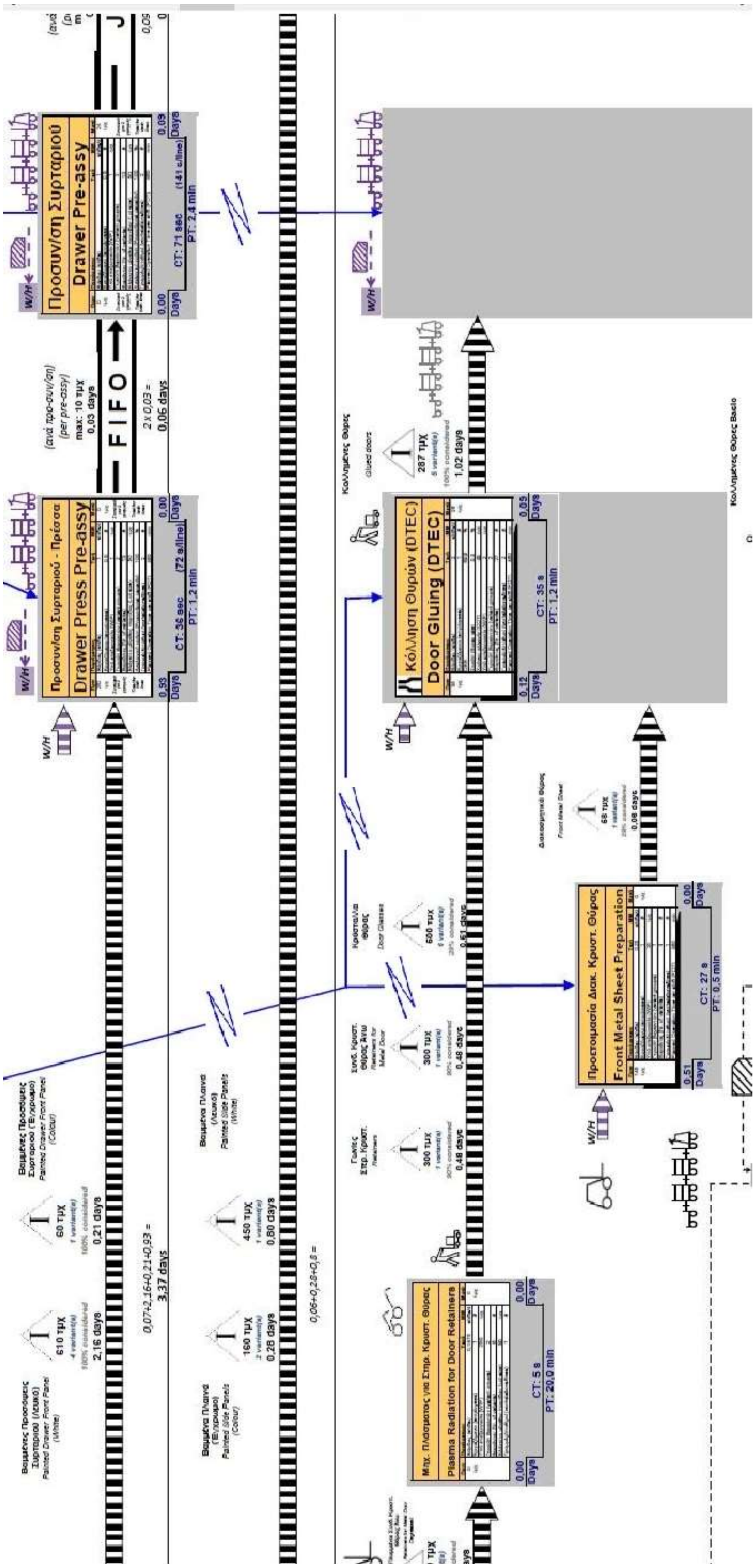
Apdx Figure 8(04): HA-OEM VSM ‘to-be’ based on DLT scenario



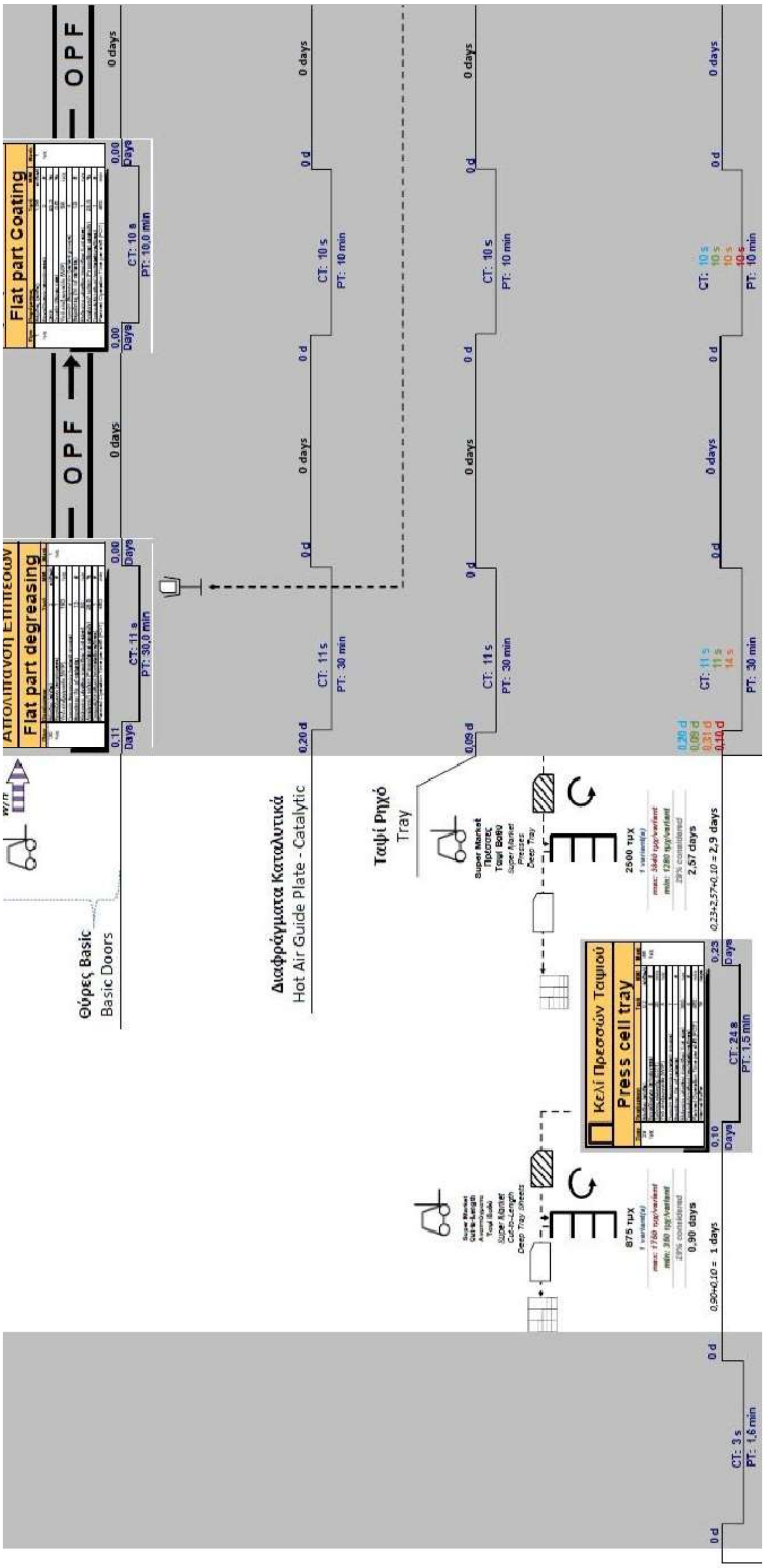
Apdx Figure 8(05): HA-OEM VSM ‘to-be’ based on DLT scenario



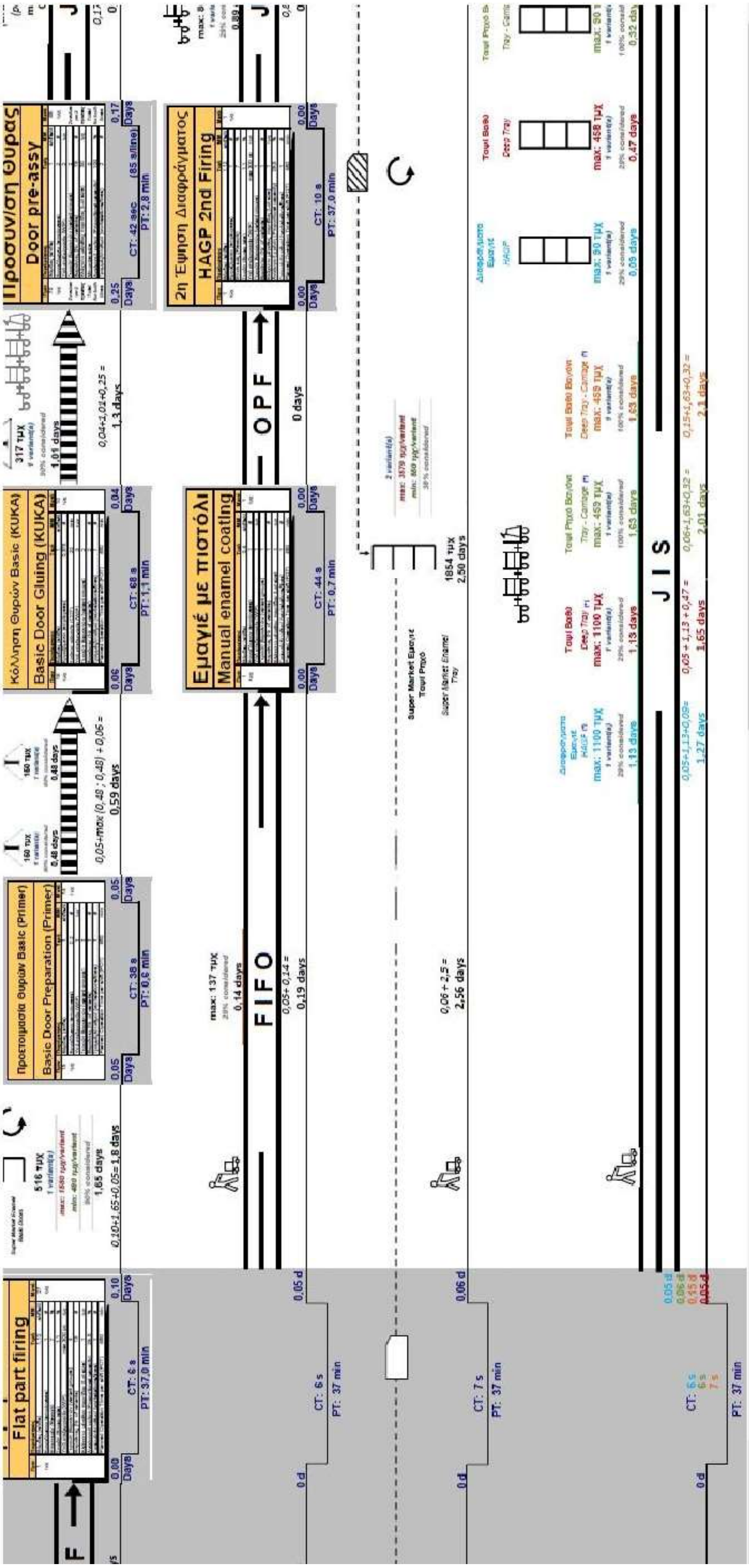
Apdx Figure 8(06): HA-OEM VSM ‘to-be’ based on DLT scenario



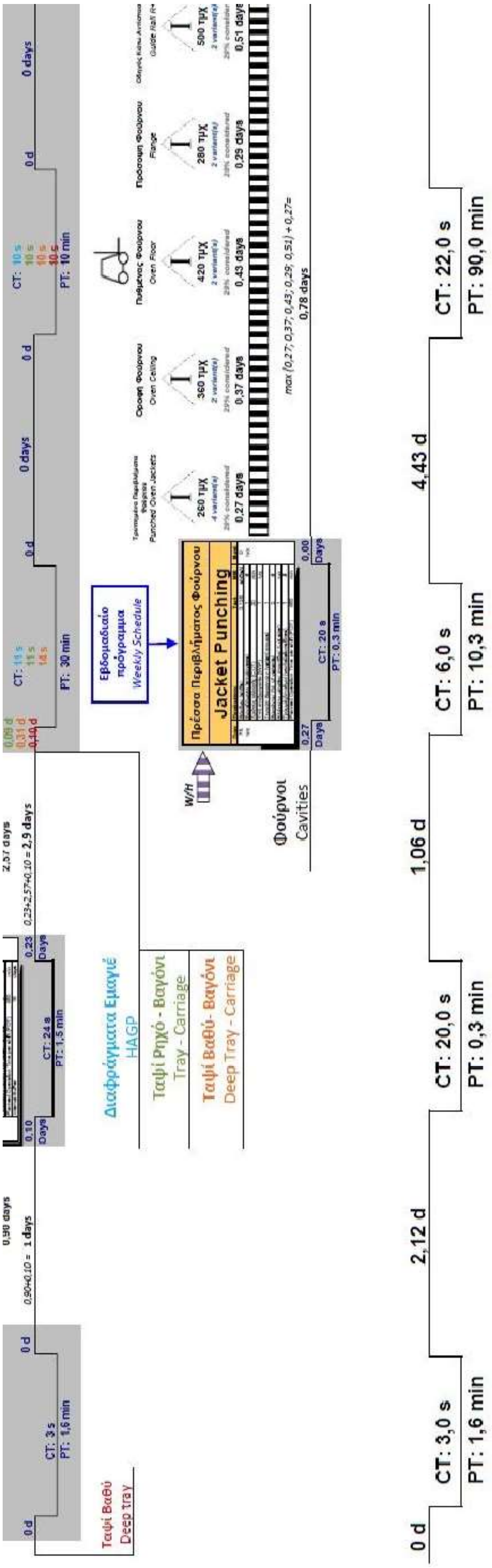
Apdx Figure 8(07): HA-OEM VSM ‘to-be’ based on DLT scenario



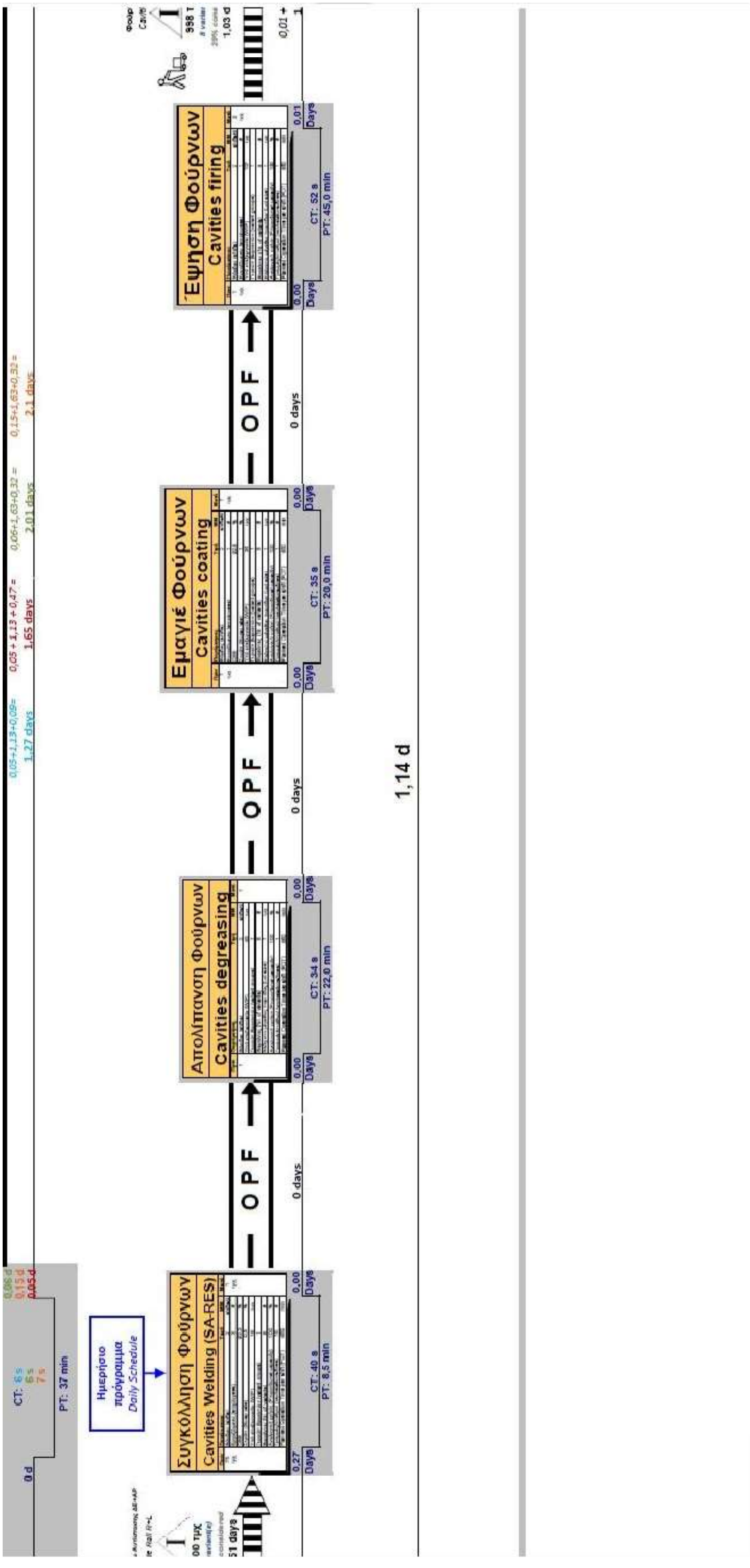
Apdx Figure 8(08): HA-OEM VSM ‘to-be’ based on DLT scenario



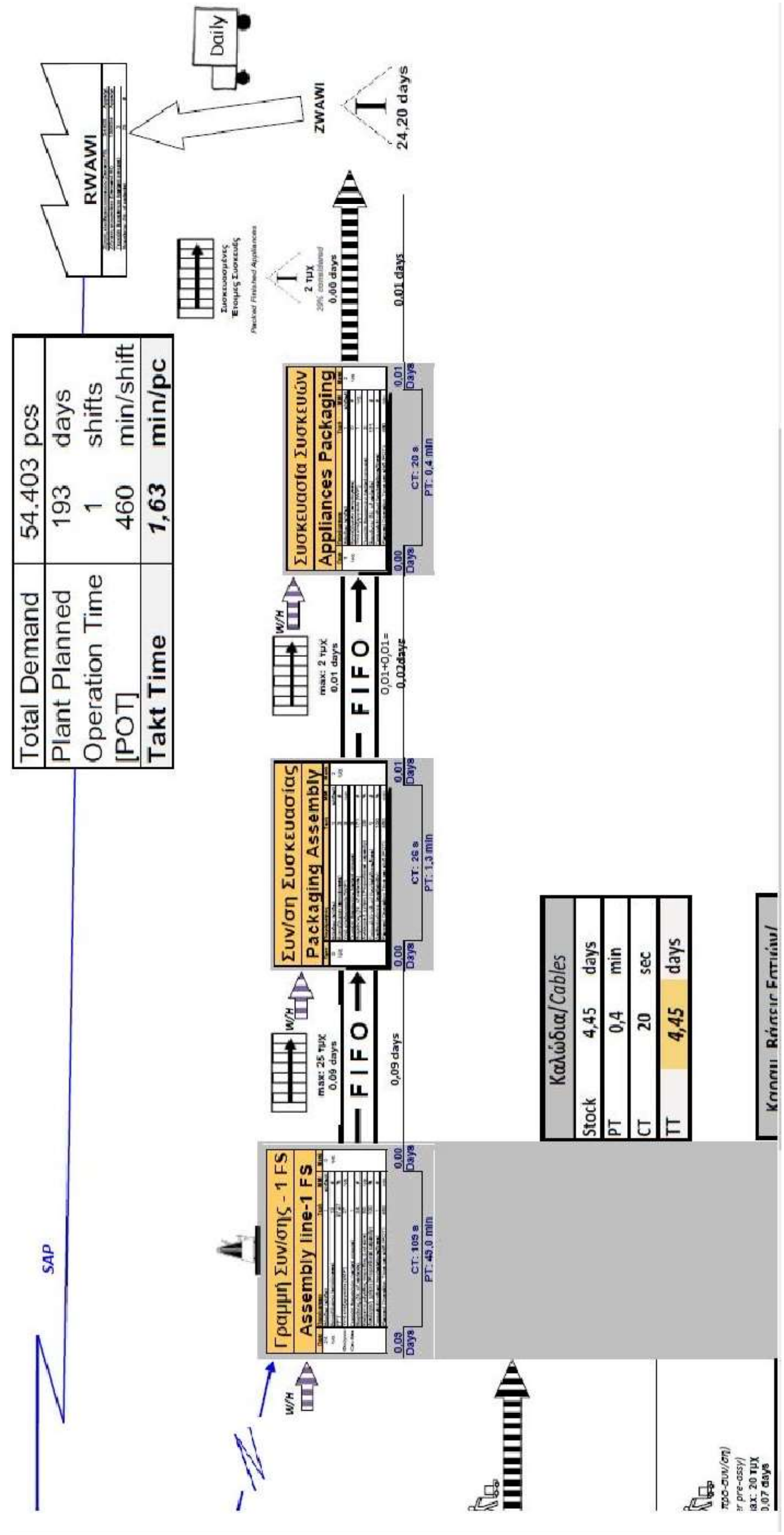
Apdx Figure 8(09): HA-OEM VSM 'to-be' based on DLT scenario



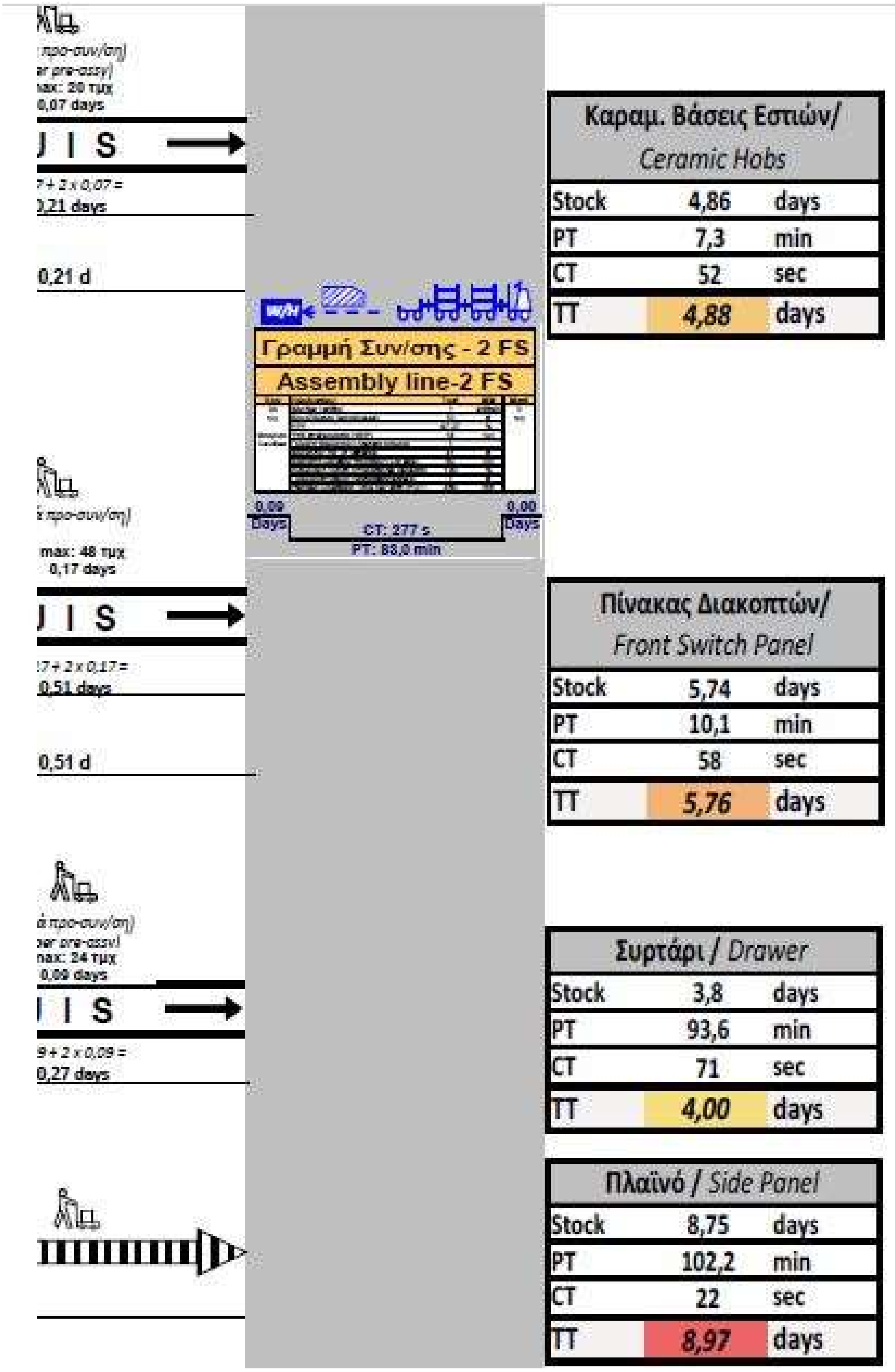
Apdx Figure 8(10): HA-OEM VSM ‘to-be’ based on DLT scenario



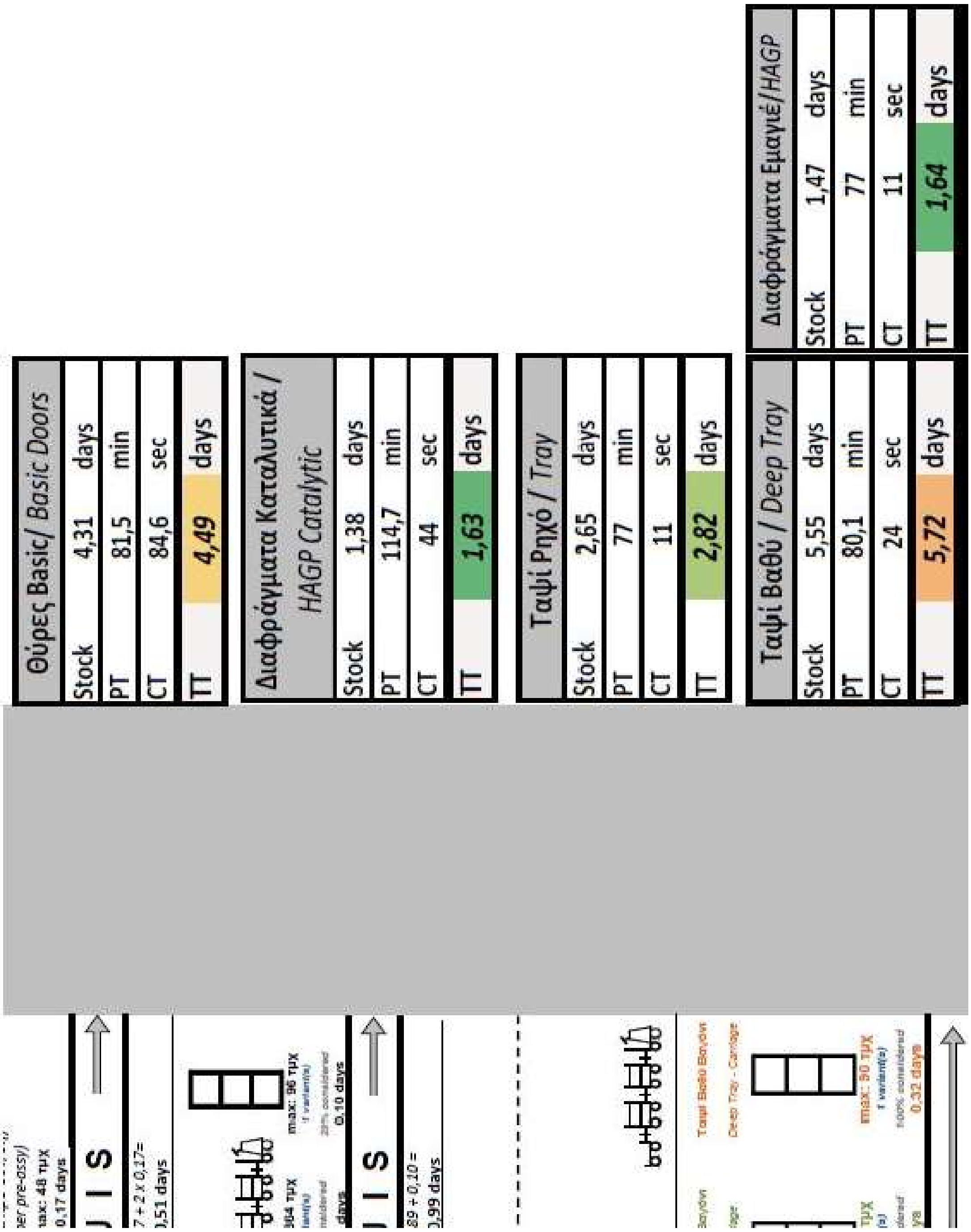
Apdx Figure 8(11): HA-OEM VSM 'to-be' based on DLT scenario



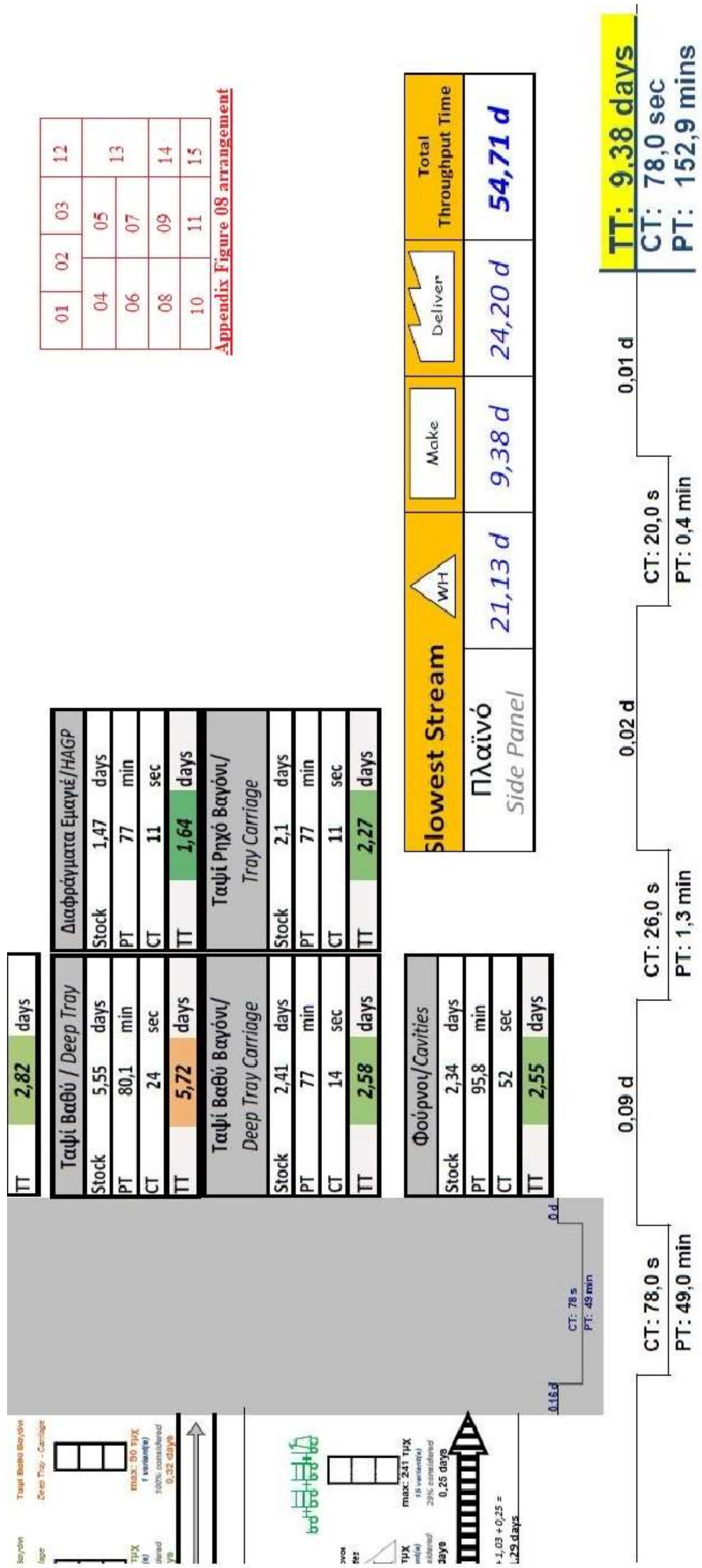
Apdx Figure 8(12): HA-OEM VSM 'to-be' based on DLT scenario



Apdx Figure 8(13): HA-OEM VSM ‘to-be’ based on DLT scenario



Apdx Figure 8(14): HA-OEM VSM ‘to-be’ based on DLT scenario



Apdx Figure 8(15): HA-OEM VSM ‘to-be’ based on DLT scenario

References

Adner, R and Kapoor R. 2010. Value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations. Strategic Management Journal; 31:306–333. https://doi.org/10.1002/smj.821

Adner, R. 2006. Match your innovation strategy to your innovation ecosystem. Harvard Business Review 84 (4), 98–107.

Agiza, et al., 1997. On a Generalized model of Biological Evolution. Journal of Statistical Physics. Vol. 88 (3/4), pp.985-989. https://doi.org/10.1023/B:JOSS.0000015183.65230.c3

Ahuja, G. 2000. Collaboration networks, structural holes, and innovation: A longitudinal study. Administrative Science Quarterly 45, 3, 425–455. https://doi.org/110.2307/2667105

Akaka, M. A., Vargo, S. L. and Lusch, R. F. 2013. The Complexity of Context: A Service Ecosystems Approach for International Marketing. Journal of International Marketing, 21(4), 1–20. https://doi.org/10.1509/jim.13.0032

Al-Ubaydli, O. and McLaughlin, P. 2014. A Numerical Database on Industry-specific Regulations for All U.S. Industries and Federal Regulations, 1997-2012. Mercatus Center, George Mason University, https://www.mercatus.org/research/working-papers/regdata

Alvesson, M. and Karreman, D. 2007. Constructing mystery: Empirical matters in theory development. Academy of Management Review, 32, 1265-1281.

Al-Shboul, M.A.R. et al 2017. The Effect of Supply Chain Management Practices on Supply Chain and Manufacturing Firms' Performance. Journal of Manufacturing Technology Management. 28.

Amaro, G., Hendry, L. and Kingsman, B.1999. Competitive advantage, customization and a new taxonomy for non-make-to-stock companies, International Journal of Operations & Production Management, 19 (4) pp. 349-371

Amit, R. and Zott, C. 2012. Creating Value Through Business Model Innovation. MIT Sloan Management Review. 53. 41-49.

Angelis, J. and Ribeiro da Silva, E. 2019. Blockchain adoption: A value driver perspective. Journal of Business Horizons. Vol 62, Issue 3,307-314 https://doi.org/10.1016/j.bushor.2018.12.001

Baden-Fuller, C. and Haefliger, S. 2013. Business models and technological innovations. Long-Range Planning, 46(6), 419–426.

Bandyopadhyay, S. 2019. Production Planning and Control, in book Machine Scheduling Problems ,pp.106-130

Bansal, P. and Corley, K. 2011. The coming of age for qualitative research: Embracing the diversity of qualitative methods. Academy of Management Journal, 54, 233-237.

Bartley, A. and Hashemi, L 2021. Quantitative data analysis and interpretation. n book: Research at Grass Roots - For the Social Sciences and Human Services Professions, Edition: 5, Chapter: 13, Publisher: Van Schaik

Basole, R. C. 2009. Visualization of interfirm relations in a converging mobile ecosystem. Journal of Information Technology ,24 (2), 144–159. https://doi.org/10.1057/jit.2008.34

Beck, R., Müller-Bloch, C. and King, J. 2018. Governance in the Blockchain Economy: A Framework and Research Agenda. Journal of the Association for Information Systems. 19. 1020-1034

Bocek, T. et al. 2017. Blockchains everywhere - a use-case of blockchains in the pharma supply-chain, 772–777.

Bock, A.J. and Gerard G. 2018. The business model book: Design, build and adapt business ideas that thrive. U.K. Pearson Education Limited

Bosch, J. 2009. From software product lines to software ecosystems. In Proceedings of the 13th International Conference on Software Product Lines (SPLC). Springer LNCS. https://doi.org/10.1145/1753235.1753251

Boschma R. 2015. Towards an Evolutionary Perspective on Regional Resilience. The Journal of the Regional Studies Association. 49.pp733-751. https://doi.org/10.1080/00343404.2014.959481

Boston Consulting Group (2019, June 26). What does a successful ecosystem look like? Available at https://www.bcg.com/publications/2019/what-does-successful-digital-ecosystem-look-like

Bφhme, R. et al. 2015. Bitcoin: Economics, technology, and governance. Journal of Economic Perspectives, 29(2), 213–238

Brass, D. J. et. al. 2004. Taking stock of networks and organizations: A multilevel perspective. Academy of Management Journal, 47(6), 795–817.

Brewer, G.D. 2007. Inventing the future: scenarios, imagination, mastery and control, Sustainability. Science. 2, 159‑177, https://doi.org/10.1007/s11625-007-0028-7

Burbidge, J. 1989. Production flow analysis, Oxford University Press, Oxford

Buterin, V., 2017.The meaning of decentralization, Ethereum Blog 6

Buterin, V., 2015. On public and private blockchains, Ethereum Blog 7

Carling, K. 2019. On Leading and Making Data-Driven Decisions, or Not. https://doi.org/10.1201/9780429298097-10

Chen D, Vallespir B, Daclin N. 2008. An Approach for Enterprise Interoperability Measurement. Conference: Proceedings of the International Workshop on Model Driven Information Systems Engineering: Enterprise, User and System Models, MoDISE-EUS'08, p. 1–12

Chesbrough, H. 2010. Business Model Innovation: Opportunities and Barriers. Long Range Planning. 43. 354-363.

Chesbrough, H. 2006. Open business models: How to thrive in the new innovation landscape. Boston, MA: Harvard Business School Press.

Chesbrough, H., and Rosenbloom, R. S. 2002. The role of the business model in capturing value from innovation: Evidence from Xerox Corporation’s technology spin-off companies. Industrial and Corporate Change, 11(3), 529–555.

Christensen C.M. 1997. Innovator’s Dilemma: When New Technologies Cause Great Firms to Fail. Harvard Business School Press: Boston, MA.

Christensen, C.M. and Rosenbloom, R. 1995. Explaining the attacker’s advantage: technological paradigms, organizational dynamics and the value network. Research Policy 24 (2), 233–257. https://doi.org/10.1016/0048-7333(93)00764-K

Christopher, M. and Towill, D. R. 2000. Supply Chain Migration From Lean and Functional to Agile and Customised, Supply Chain Management: An International Journal, Vol 5 . Nr 4 . pp. 206±213, https://doi.org/10.1108/13598540010347334

Crandall, R. E and Burwell, T.1993. The effect of work-in-progress inventory levels on throughput and lead times. Production and Inventory Management Journal; Alexandria Vol. 34, Iss. 1,

Creswell, JW. 1999. Chapter 18 - Mixed-Method Research: Introduction and Application, In Educational Psychology, Handbook of Educational Policy, Academic Press,Pages 455-472, https://doi.org/10.1016/B978-012174698-8/50045-X.

Cusumano, M.A. and Gawer, A. 2002. The elements of platform leadership. MIT Sloan Management Review, 51-58. https://doi.org/10.1109/EMR.2003.1201437

Dahan, N., et. al. 2010. Corporate NGO Collaboration: Co-Creating New Business Models for Developing Markets. Long Range Planning 43 (2-3), 326e342.

Davis, N. et al. 2020. 4th Industrial Revolution Design Through Lean Foundation, Procedia CIRP, Vol 91,p306-311 ,https://doi.org/10.1016/j.procir.2020.03.102.

De Boer, L., Labro, E. and Morlacchi, P. 2001. A review of methods supporting supplier selection, European Journal of Purchasing & Supply Management, Vol. 7, pp. 75-89

Deloitte insights. 2019. Many paths lead to blockchain adoption, and no two are alike. An industry-by-industry look. Deloitte's 2019 Global Survey. Retrieved Nov 01 2019 from www.deloitte.com/insights.

Doney, P. M. and Cannon, J. P. 1997. An examination of the nature of trust in buyer-seller relationships. Journal of Marketing, 61(2), 35-51.

Donselaar, K.V., Kopczak, L.R. and Wouters M. 2001. The use of advance demand information in a project-based supply chain European Journal of Operational Research, 130 (3), pp. 519-538

Dougherty, D. and Dunne, D.D. 2011. Organizing ecologies of complex innovation, Organization Science, Vol. 22 No. 5, pp. 1214-1223. https://doi.org/10.1287/orsc.1100.0605

Dupuis, D. 1999. Exceedances over High Thresholds: A Guide to Threshold Selection. Extremes 1, 251–261. https://doi.org/10.1023/A:1009914915709

Eisenhardt, K.M. 2021. What is the Eisenhardt Method, really?. Strategic Organization. 19. 147-160.

Eisenhardt, K.M. 1989. Building theories from case study research. Academy of Management Review, 14(4), 532- 550.

Eisenhardt, K. M. and Graebner, M. E. 2007. Theory building from cases: Opportunities and challenges. Academy of Management Journal, 50(1), 25-32,

Eisenhardt, K.M. and Schoonhoven, C.B. 1996. Resource-based view of strategic alliance formation: Strategic and social effects in entrepreneurial firms. Organization Science, 7, 2 (1996), 136–150. https://doi.org/10.1287/orsc.7.2.136

El Sawy, O. A. and Pereira, F. 2013. Business Modelling in the Dynamic Digital Space, Springer Briefs in Digital Spaces

Ernst, A et al .2018. Benefits and challenges of participatory methods in qualitative energy scenario development, Technological Forecasting and Social Change, Vol 127, Pages 245-257, https://doi.org/10.1016/j.techfore.2017.09.026.

European Commission. 2003. SME definition | Internal Market, Industry, Entrepreneurship and SMEs (europa.eu) https://ec.europa.eu/growth/smes/sme-definition_en

Falcone, R. and Castelfranchi, C. 2001. Social trust: a cognitive approach. In Trust and Deception in Virtual Societies, pages 55–90. Kluwer Academic Publishers Norwell, MA, USA.

Ferreira, J. et al. 2019. A Systematic Literature Review in Blockchain: Benefits and Implications of the Technology for Business. https://doi.org/10.1007/978-3-030-16181-1_38.

Fernandez-Carames T.M. and Fraga-Lamas, P. 2016. A review on the use of Blockchain for the Internet of Things, IEEE Access 6, 2169–3536, https://doi.org/10.1109/ACCESS.2018.2842685

Fielt, E. 2013. Conceptualising Business Models: Definitions, Frameworks and Classifications. Journal of Business Models. 1. 85-105.

Fjeldstad, Ø.D. and Snow, C.C. 2018. Business Models and Organization Design, Long Range Planning, 51(1) 32–39.

Frels, J.K., Tasadduq S., and Rajendra K.S. 2003. The Integrated Networks Model: Explaining Resource Allocations in Network Markets. Journal of Marketing 67 (1): 29-45. https://doi.org/10.1509/jmkg.67.1.29.18586

Gambelli, D., Vairo, D. and Zanoli, R. 2010. Exploiting Qualitative Information for Decision Support in Scenario Analysis, Journal of Decision Systems, 19:4, 407-422, https://doi.org/10.3166/jds.19.407-422

Gassmann O.et al. 2013. The business model navigator, Pearson Education Ltd, UK

Gaya HJ. et al. 2016. Developing a Qualitative Single Case Study in the Strategic Management Realm: An Appropriate Research Design?, International Journal of Business Management and Economic Research(IJBMER), Vol 7(2),529-538

Gausdal, A.H., Svare, H and Möllering. G. 2016. Why don't all high-trust networks achieve strong network benefits? A case-based exploration of cooperation in Norwegian SME networks, Journal of Trust Research, 6:2, 194-212

Gawer A. and Cusumano M.A. 2014. Industry Platforms and Ecosystem Innovation. Journal of Product Innovation Management.31(3),417-433. https://doi.org/10.1111/jpim.12105

Gelders, L.F. and Van Wassenhove, L.N. 1981. Production planning: a review, European Journal of Operational Research, Elsevier, vol. 7(2), pages 101-110, June.

Gioia, D., Corley, K. and Hamilton, A. 2013. Seeking Qualitative Rigor in Inductive Research. Organizational Research Methods. 16. 15-31. https://doi.org/10.1177/1094428112452151.

Gioia, D. A. and Pitre, E. 1990. Multiparadigm perspectives on theory building. Academy of Management Review, 15, 584-602.

Glaser, D. and Strauss, A. 1967 The Discovery of Grounded Theory. Chicago, IL: Aldine.

Gopal, P.R.C. and Thakkar, J. 2012. A review on supply chain performance measures and metrics: 2000-2011, International Journal of Productivity and Performance Management, Vol. 61 No. 5, pp. 518-547

Gosling, J. and Naim, M. 2009. Engineer-to-order supply chain management: A literature review and research agenda, International Journal of Production Economics, Volume 122, Issue 2, 2009, Pages 741-754,

Green, D. G. and Sadedin, S. 2005. Interactions matter complexity in landscapes and ecosystems. Ecological Complexity 2(2), 117–130. https://doi.org/10.1016/j.ecocom.2004.11.006

Guest, G., Bunce, A.and Johnson, L 2006. How many interviews are enough? An experiment with data saturation and variability. Field Methods 18:59–82.

Gulati, R., Nohria, N. and Zaheer, A. 2000. Strategic networks. Strategic Management Journal 21, 3 (2000), 203–215. https://doi.org/0.1002/%28SICI%291097-0266%28200003%2921%3A3%3C203%3A%3AAID-SMJ102%3E3.0.CO%3B2-K

Hannan, MT. and Freeman, J. 1997. The population ecology of public organizations. American Journal of Sociology.Vol82, https://doi.org/10.1086/226424.

Haoyan, W et al. 2017. A Distributed Ledger for Supply Chain Physical Distribution Visibility. Journal of Information. 8. 137, https://doi.org/10.3390/info8040137

Hauptman, O. 2003. Platform Leadership: How Intel, Microsoft and Cisco Drive Industry Innovation. Innovation: Management, Policy & Practice. 5. 91-94. https://doi.org/10.5172/impp.2003.5.1.91.

Hartmann, L., et al. 2018. Value stream method 4.0: holistic method to analyse and design value streams in the digital age. Procedia CIRP. 78. 249-254. https://doi.org/10.1016/j.procir.2018.08.309.

Hemalatha, C., Sankaranarayanasamy, K. and Durairaaj, N. 2021.Lean and agile manufacturing for work-in-process (WIP) control, Materials Today: Proceedings, Vol 46, Part 20 ,https://doi.org/10.1016/j.matpr.2020.12.473.

Hendry, L.C., Kingsman, B.G. and Amaro, G.M. 2003. Product customization and competitive advantage: an empirical study. EUROMA Conf. Pro., 1, 119–128.

Herriott, R. E., and Firestone, W. A. 1983. Multisite qualitative policy research: Optimizing description and generalizability. Educational Researcher, 12, p14–19.

Hicks, T. and McGovern, E. 2001. A typology of UK engineer-to-order companies International Journal of Logistics, 4 (2001), pp. 43-56

Hoekstra, J. R. 1992. Integral Logistics Structures: Developing Customer Oriented Goods Flow, McGraw-Hill, London

Holmström, J. et al. 2019. The digitalization of operations and supply chain management: Theoretical and methodological implications, Journal of Operations Management,Wiley Periodicals, Inc

Hoop, W. J. and Spearman, M. L. 2004. To Pull or Not to Pull: What is the Question? Manufacturing & Service Operations Management, v .6, n .2, 2004.

Hofer, A.R., Knemeyer, A.M. and Dresner, M.E. 2009. Antecedents and Dimensions of Customer partnering behavior in logistics outsourcing relationships. Journal of Business Logistics, 30(2), 141-159.

Hu, M. and Monahan, S. 2015. Sharing Supply Chain Data in the Digital Era. MIT Sloan Management Review. 57. 95-+.

Huin, S.F., Luong, L.H.S. and Abhary, K. 2002. Internal supply chain planning determinants in small and medium-sized manufacturers, International Journal of Physical Distribution & Logistics Management, Vol. 32 No. 9, pp. 771-782.,

Iansiti, M. and Lakhani, K. R. 2017. The truth about blockchain. Harvard Business Review, 95(1), 118–127.

Iansiti, M and Levien, R. 2004. The Keystone Advantage: What New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability. Harvard Business School Press, Boston, MA.

Iansiti, M., and Richards, G. L. 2006. The Information Technology Ecosystem: Structure, Health, and Performance. The Antitrust Bulletin, 51(1), 77–110, https://doi.org/10.1177/0003603X0605100104

Ibarra, H. and Hansen, M. T. 2011. Are you a collaborative leader? Harvard Business Review, 89, 7/8 (2011), 68–74.

IBM Institute for Business Value., 2017. Next Generation Supply Chain powered by Cognitive and Blockchain; Technical Report, Digital Supply Chain, International Business Machines Corporation: Armonk, NY, USA

Ibrahim, M. and Ribbers, P. M. 2009. The impacts of competence-trust and openness-trust on interorganizational systems. European Journal of Information Systems, 18(3), 223-234

Isckia T., Lescop D., 2009. Open Innovation within Business Ecosystems: A Tale from Amazon.com. Communications & Strategies. 1. 37-54.

Jansen, S., Brinkkemper, S. and Finkelstein, A. 2013. Business network management as a survival strategy. Software Ecosystems: Analyzing and Managing Business Networks in the Software Industry. 29-42. https://doi.org/10.4337/9781781955628.00009.

Jansen,S., Finkelstein, A. and Brinkkemper, S. 2009. A sense of community: A research agenda for software ecosystems. In 31st International Conference on Software Engineering, New and Emerging Research Track, pages 187–190, https://doi.org/10.1109/ICSECOMPANION. 2009.5070978

Jick, T. D.1979. Mixing qualitative and quantitative methods: Triangulation in action. Administrative Science Quarterly, 24: 602–611.

Johannessen, J., Olaisen, J. and Olsen, B., 2001. Mismanagement of tacit knowledge: the importance of tacit knowledge, the danger of information technology, and what to do about it, International Journal of Information Management, Volume 21, Issue 1, Pages 3-20, ISSN 0268-4012, https://doi.org/10.1016/S0268-4012(00)00047-5

Johnson, D. 2003. A framework for reducing manufacturing throughput time, Journal of Manufacturing Systems, Vol 22, Issue 4, p283-298, https://doi.org/10.1016/S0278-6125(03)80009-2.

Johnson, M. W. 2010. Seizing the white space: Business model innovation for growth and renewal. Boston, MA: Harvard Business Press

Johnson, M.W., Christensen, C.M. and Kagermann, H. 2008. Reinventing Your Business Model. Harvard Business Review, 86(12), 50-59.

Kaartemo, V., Akaka, M. and Vargo, St. 2017. A Service-Ecosystem Perspective on Value Creation: Implications for International Business. In Svetla M., Jorma L. and Niina Nummela, Value Creation in International Business (pp.131-149). Vol. 2: An SME Perspective. Springer International Publishing. https://doi.org/10.1007/978-3-319-39369-8_6

Kaiser, C., Stocker, A., Viscusi, G., Fellmann, M., Alexander Richter, A., 2021. Conceptualising value creation in data-driven services: The case of vehicle data, International Journal of Information Management, Volume 59, 102335, ISSN 0268-4012, https://doi.org/10.1016/j.ijinfomgt.2021.102335

Kan, A. 1976. General flow-shop and job-shop problems, Machine Scheduling problems, pp106-130

Karakas F. 2009. Welcome to World 2.0: the new digital ecosystem. Journal of Business Strategy, 30:23–30. https://doi.org/10.1108/02756660910972622.

Kaushik, A. et al. 2017. Blockchain — Literature survey, 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), 2017, pp. 2145-2148

Kingsman, B. and Souza, A. 1997. A knowledge-based decision support system for cost estimation and pricing decisions in versatile manufacturing companies. International Journal of Production Economics. 53. 119-139.

Klüber, R. and O'Keefe, R. 2013. Defining and assessing requisite supply chain visibility in regulated industries. Journal of Enterprise Information Management. 26.

Korpela, K., Kuusiholma, U., Taipale, O. and Hallikas, J. 2013. A Framework for Exploring Digital Business Ecosystems. Proceedings of the Annual Hawaii International Conference on System Sciences. 10. https://doi.org/10.1109/HICSS.2013.37

Kotabe, M., Arvind, S., and Preet, S.A. 1996. Emerging Role of Technology Licensing in the Development of Global Product Strategy: Conceptual Framework and Research Propositions, Journal of Marketing, 60 (January), 73–88. https://doi.org/10.1177/002224299606000107

Koteska, E., et al., 2017. 6th Workshop of Software Quality, Analysis, Monitoring, Improvement, and Applications. Belgrade, Serbia, 11-13 September 2017 Blockchain Implementation Quality Challenges: A Literature Fig. A2. Search and selection process of the studies. G. Zhao et al. / Computers in Industry 109 (2019) 83–99

Kumar, S.V., Mani, V.G.S. and Devraj. N. 2014.Production Planning and Process Improvement in an Impeller Manufacturing Using Scheduling and OEE Techniques,Procedia Materials Science,Volume 5,p 1710-1715, https://doi.org/10.1016/j.mspro.2014.07.360.

Kvale, S. 1996. Interviews: An Introduction to Qualitative Research Interviewing. Sage Publications Ltd, London.

Lambkin, M. and George S.D. 1989. Evoluationary Processes in Competitive Markets: Beyond the Product Life Cycle. Journal of Marketing, 53 (July), 4–20. https://doi.org/10.1177/002224298905300304

Lawrence, K. 2011. The Supply Chain in Manufacturing, Distribution and Transportation. CRC Press Taylor& Francis

Lee, J. H. and Pilkington, M. 2017. How the Blockchain revolution will reshape the consumer electronics industry. IEEE Consumer Electronics Magazine, 6(3), 19–23

Lesshammar, M. 1999. Evaluation and improvement of manufacturing performance measurement systems – the role of OEE, International Journal of Operations and Production Management, vol. 19, no. 1, pp. 55-78, (1999). https://doi.org/10.1108/01443579910244223

Lenkenhoff, K., Wilkens, U., Zheng, M., Suesse, T., Kuhlenkötter, B. and Ming, X. 2018. Key challenges of digital business ecosystem development and how to cope with them. Procedia CIRP. 73. 167-172. https://doi.org/10.1016/j.procir.2018.04.082

Lewicki, R. J., Tomlinson, E. C. and Gillespie, N. 2006. Models of Interpersonal Trust Development: Theoretical Approaches, Empirical Evidence, and Future Directions. Journal of Management, 32(6):991–1022.

Lewin, R. 1999. Complexity: Life at the Edge of Chaos. The University of Chicago Press, 234p.

Li, D., 2018. The ever-evolving business ecosystem. Business Horizons. 61. 10. https://doi.org/10.1016/j.bushor.2018.02.003

Li, Y., 2009. The technological roadmap of Cisco's business ecosystem. Technovation 29, 379-386. https://doi.org/10.1016/j.technovation.2009.01.007

Li, Z. et al .2018. A Hybrid Blockchain Ledger for Supply Chain Visibility, 2018 17th International Symposium on Parallel and Distributed Computing (ISPDC), pp. 118-125

Lincoln, Y. and Guba. E. 1985. Naturalistic Inquiry. Beverly Hills, CA: Sage.

Liu, L. and Ran, W. 2020. Research on supply chain partner selection method based on BP neural network. Neural Comput & Applic 32, 1543–1553

Locke, K. 1996. Rewriting the Discovery of Grounded Theory after 25 years?. Journal of Management Inquiry, 5: 239–245.

Lusch, R. 2011. Reframing supply chain management: A service-dominant logic perspective. Journal of Supply Chain Management. 47. 14 – 18. https://doi.org/10.1111/j.1745-493X.2010.03211.x

Lymperopoulos, C., Chaniotakis, I. E. and Rigopoulou, I. D. 2010. Acceptance of detergent-retail brands: The role of consumer confidence and trust. International Journal of Retail & Distribution Management, 38(9), 719-736.

Magretta, J. 2002. Why business models matter?, Harvard Business Review, Vol. 80, No. 5, pp.86–92.a

Makinen, S.J. and Dedehayir, O. 2012. Business ecosystem evolution and strategic considerations: A literature review. 18th International Conference on Engineering, Technology and Innovation, ICE 2012 - Conference Proceedings. 1-10. https://doi.org/10.1109/ICE.2012.6297653

Marsh, S. 1994. Formalising trust as a computational concept. PhD thesis, University of Stirling

Mason-Jones, R. and Towill, D.R. 1997. Information enrichment: designing the supply chain for competitive advantage, Supply chain management, Vol 2, No4, pp137-148.

Mayer, R., Davis, J. and Schoorman, F. 1995. An integrative model of organizational trust. Academy of Management Review, 20(3):709–734.

McIntyre, S. H. 1988. Market Adaptation as a Process in the Product Life Cycle of Radical Innovations and High Technology Products, Journal of Product Innovation Management, 5 (2), 140–49. https://doi.org/10.1016/0737-6782(88)90005-7

McKinsey & Company. 2018. Blockchain beyond the hype: What is the strategic business value? Retrieved Jun 30 2018 from https://www.mckinsey.com

McKone,K., Schroeder,R. and O Cua,K. 2001.The impact of total productive maintenance practices on manufacturing performance, Journal of Operations Management,Vol 19, Issue 1,p 39-58, https://doi.org/10.1016/S0272-6963(00)00030-9.

McLaughlin-Sherouse.2014. The 10 Most-Regulated Industries. https://www.mercatus.org/publications/regulation/mclaughlin-sherouse-list-10-most-regulated-industries-2014

Meissner, P. and Wulf, T. 2013. Cognitive benefits of scenario planning: its impact on biases and decision quality. Technological Forecasting and Social Change. 80, 801–814, https://doi.org/10.1016/j.techfore.2012.09.011

Miles, M. and Huberman, M. 1994. Qualitative Data Analysis: An Expanded Sourcebook, 2d ed. Newbury Park, CA: Sage.

Mingzhen, Y. 2021. Order Acceptance and Scheduling for Make-to-Order Manufacturing Enterprises. 10.1007/978-981-33-4359-7_70

Mohammadali V., Atour T. and Canel-Depitre, B. 2020. Supply chain coordination under information asymmetry: a review, International Journal of Production Research, 58:6, 1805-1834,

Monrat, A.A., Schelén, O. and K. Andersson, K. 2019. A Survey of Blockchain From the Perspectives of Applications, Challenges, and Opportunities, *IEEE Access*, vol. 7, pp. 117134-117151, 2019, https://doi.org/10.1109/ACCESS.2019.2936094.

Moore, J.F. 2006. Business ecosystems and the view from the firm. The antitrust Bulletin. Vol. 51, No. I/Spring 2006 p. 53, https://doi.org/10.1177/0003603X0605100103

Moore, J.F. 1996. The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems. New York, Harper Business, 297p.

Moore, J.F. 1993. Predators and Prey: The New Ecology of Competition. Harvard Business Review. Vol. 71(3), pp. 75-83.

Mor, R.S., et al. 2019. Productivity gains through standardization-of-work in a manufacturing company, Journal of Manufacturing Technology Management, Vol. 30 No. 6, pp. 899-919.

Morris, M.H., Schindehutte, M., and Allen, J. 2005. The entrepreneur's business model: Toward a unified perspective. Journal of Business Research, 58(6), 726-735.

Nakajima, S. 1988. Introduction to TPM, Productivity Press, Cambridge, MA., 1988.

Naylor, J.B., Naim, M.M. and Berry. D 1999. Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain International Journal of Production Economics, 62 (1,2), pp. 107-11

Nicta,V.G. 2016. On the Danger of Private Blockchains, when PoW can be Harmful to Applications with termination Requirements. Computer Science,Mathematics Journal

Nofer, M., et al. 2017. Blockchain. Business & Information Systems Engineering, 59(3), 183–187.

OECD, 2014. The digital economy, new business models and key features, in Addressing the Tax Challenges of the Digital Economy, OECD Publishing, Paris

Oracle, 2017. Oracle Database Concepts, 12c Release 1 (2017) Available at https://docs.oracle.com/database/121/CNCPT/E41396-15.pdf

Ortiz C.A. 2008. Lessons from a Lean Consultant: Avoiding Lean Implementation Failures on the Shop Floor. Pearson Education

Osterwalder, A., Parent, C. and Pigneur, Y. 2004. Setting up an ontology of business models. In Proceedings of 16th International Conference on Advanced Information Systems Engineering (CAiSE03) Workshops (3). pp. 319–324.

Osterwalder, A. and Pigneur, Y. 2010. Business model generation: A handbook for visionaries, game changers, and challengers. Wiley, New Jersey.

Osterwalder, A., et al. 2005. Clarifying business models: Origins, present, and future of the concept. Communications of the Association for Information Systems 16, 16(1).

Papanikolaou, E., Angelis, J. and Moustakis, V. 2023.Unique or adjustable business model for DLT? Journal of Business Models, Vol 11, https://doi.org/10.54337/jbm.v11i1.7149

Papanikolaou, E., Angelis, J. and Moustakis V. 2021. Implicit business model effects of DLT adoption. Procedia CIRP, Vol 103, p 298-304, https://10.1016/j.procir.2021.10.048

Papanikolaou, E., Angelis, J. and Moustakis, V. 2023. Which type of ecosystem for Distributed Ledger Technology? Journal of Technology in Society, Vol 72, https://doi.org/10.1016/j.techsoc.2022.102143

Pateli, A. G. and Giaglis, G. M. 2004. A research framework for analysing eBusiness models. European Journal of Information Systems, 13(4), 302-314.

Peltoniemi, M. and Vuori, E. 2008. Business Ecosystem as the New Approach to Complex Adaptive Business Environments. Proceedings of EBusiness Research Forum.

Peltoniemi, M., Vuori, E. and Laihonen, H. 2005. Business ecosystem as a tool for the conceptualisation of the external diversity of an organization. Proceedings of Complexity, Science & Society Conference 2005, Liverpool, UK

Plenert, G. 1999. Focusing material requirements planning (MRP) towards performance. European J. Op. Res., 1999, 119, 91–99.

Pilkington. M. 2016. Research Handbook on Digital Transformations. Edwards Elgar Publishing Ltd, Uk,225-253

Plossl, GW. 1988. Throughput time control, International Journal of Production Research, 26:3, 493-499, https://doi.org/10.1080/00207548808947879

Poppe,J. et al. 2017. Numerical study of inventory management under various maintenance policies, Reliability Engineering & System Safety, Vol 168, p 262-273, https://doi.org/10.1016/j.ress.2017.06.012.

Power, T. and Jerjian, G. 2001. Ecosystem: Living the 12 principles of networked business. Pearson Education Ltd. 392 p.

Pratt, M. G. 2008. Fitting oval pegs into round holes: Tensions in evaluating and publishing qualitative research in top-tier North American journals. Organizational Research Methods, 11, 481-509

Qian, Y. et al. 2012. Information Sharing in a Competitive Supply Chain with Capacity Constraint. Flexible Services and Manufacturing Journal 24 (4): 549–574.

Ramakrishna, Y. 2016. Supply Chain Management: Large vs. Small and Medium Enterprises (SMEs).https://doi.org/10.4018/978-1-4666-9795-9.ch009

Ramayah, T. and Roaimah, O. 2010. Information exchange and supply chain performance. International Journal of Information Technology & Decision Making.

Reyna, A., et al., 2018. On blockchain and its integration with IoT. challenges and opportunities, Future Gener. Comput. Syst. 88, 173–190. https://doi.org/10.1016/j.future.2018.05.046

Richards, D. 1996. Elite interviewing: Approaches and pitfalls. Politics, 16(3), 199–204.

Robert K.Y. 2018. Case study research and applications 6th editions, Sage Inc

Roda, I. and Macchi,M. 2019. Factory-level performance evaluation of buffered multi-state production systems,Journal of Manufacturing Systems,Vol 50,p226-235,https://doi.org/10.1016/j.jmsy.2018.12.008

Rother, M. and Shook. J. 2003. Learning to See. pp. 10-22, Lean Enterprise Institute, Cambridge, MA USA

Rubin, H. J. and Rubin, I. S. (2011). Qualitative interviewing: The art of hearing data (3rd ed.). Thousand Oaks, CA: Sage.

Rückeshäuser, N. 2017. Typology of distributed ledger based business models. In Proceedings of the European Conference on Information Systems (pp. 2202–2217), Guimareas.

Rus, A. 2005. Trust and performance: Institutional, interpersonal and network trust. In K. Bijlsma-Frankema & R. K. Woolthuis (Eds.), Trust under pressure: Empirical investigations of trust and trust building in uncertain circumstances (pp. 80–104). Cheltenham: Edward Elgar.

Sabater, J. and Sierra, C. 2002. Reputation and social network analysis in multi-agent systems. In Proceedings of the first international joint conference on Autonomous agents and multi agent systems: part 1, pages 482–490. ACM.

Sahay, B.S. 2003. Understanding trust in supply chain relationships, Industrial Management & Data Systems, Vol. 103 No. 8, pp. 553-563,

Salum, F. 2019. The Business Models' Value Dimensions: An Analytical Tool. Revista Ibero-Americana de Estratégia. 18. 438-459

Salviotti, G., et al., 2018. A structured framework to assess the business application landscape of blockchain technologies. Proceedings of the 51st Hawaii International Conference in System Sciences. https://doi.org/10.24251/HICSS.2018.440

Schallmo, D. 2013. Geschäftsmodelle erfolgreich entwickeln und implementieren. Berlin: Springer - Verlag

Senyo, P., Liu, K., Effah, J., 2019. Digital business ecosystem: Literature review and a framework for future research, International Journal of Information Management, Volume 47, Pages 52-64, ISSN 0268-4012, https://doi.org/10.1016/j.ijinfomgt.2019.01.002

Sha, D.Y. and Che, Z.H. 2006. Supply chain network design: partner selection and production/distribution planning using a systematic model, Journal of the Operational Research Society, 57:1, 52-62

Shafer. S, Smith, H. and Linder, J. 2005. The power of business models, Business Horizons, Vol 48, pp 199-207.

Shapiro, C. and Variahn H.R. 2008. A strategic guide to the network economy. Boston. Harvard Business School Publishing. https://doi.org/10.2307/1183273

Singh, S., Khamba, J.S., Singh, D. 2021. Analyzing the Role of Six Big Losses in OEE to Enhance the Performance: Literature Review and Directions. In: Phanden, R.K., Mathiyazhagan, K., Kumar, R., Paulo Davim, J. (eds) Advances in Industrial and Production Engineering. Lecture Notes in Mechanical Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-33-4320-7_37

Smith, B. (2018). Generalizability in qualitative research: misunderstandings, opportunities and recommendations for the sport and exercise sciences. Qualitative Research in Sport, Exercise and Health, 10(1), 137–149. https://doi.org/10.1080/2159676X.2017.1393221

Smith, J. 2016. Blockfreight: Blockchain Technology for Global Freight. Technical Report. Available at https://blockchainlab.com/pdf/BlockfreightWhitepaperFinalDraft.pdf

Soman, C.A., et al. 2004. Combined make-to-order and make to- stock in a food production system. Int. J. Prod. Econ., 2004

Somapa, S., Cools, M. and Dullaert, W. 2018. Characterizing supply chain visibility – a literature review, The International Journal of Logistics Management, Vol. 29 No. 1, pp. 308-339

Spearman, M.L. and Hopp, W.J. 1998. Teaching operations management from a science of manufacturing. Production and Operations Management, 7: 132-145. https://doi.org/10.1111/j.1937-5956.1998.tb00445.x

Spring, M. and Dalrymple, J. 2000. Product customisation and manufacturing strategy. Int. J. Op.and Prod. Manage., 20, 441–467

Srivannaboon, S. 2009. Achieving Competitive Advantage through the use of Project Management under the Plan-do-Check-act Concept. Journal of General Management.34(3):1-20.

Statista .2023. Home & household appliances - Statistics & Facts | Statista https://www.statista.com/topics/1068/home-appliances/

Statista. 2019. Major home appliances companies revenue ranking 2019 | Statista https://www.statista.com/statistics/266689/net-sales-of-leading-home-appliance-manufacturers-worlwide/

Stevenson, M., Hendry, L and Kingsman, B.G. 2005. A review of production planning and control: The applicability of key concepts to the make-to-order industry. International Journal of Production Research - INT J PROD RES. 43. 869-898.

Strauss, A. and Corbin, J. 1998. Basics of qualitative research: Techniques and procedures for developing grounded theory (2nd ed.). Thousand Oaks, CA: Sage

Suri, R. 1998. Quick Response Manufacturing: A Companywide Approach to Reducing Lead Times. Portland: Productivity Press, 1998

Suryaprakash, M. et. al. 2021. Improvement of overall equipment effectiveness of machining centre using TPM, Materials Today: Proceedings, Vol 46, Part 19, p9348-9353, https://doi.org/10.1016/j.matpr.2020.02.820.

Teece, D.J. 2010. Business models, business strategy and innovation. Long Range Planning, 43(2-3), 172-194.

Teece, D. 2007. Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. Strategic Management Journal 28, 1319-1350. https://doi.org/10.1002/smj.640

Tennant G. 2001. SIX SIGMA: SPC and TQM in Manufacturing and Services, Gower Publishing, Ltd. p. 6. ISBN 0-566-08374-4, p.p30-33

Timans, R., Wouters, P. and Heilbron, J. 2019. Mixed methods research: what it is and what it could be. Theory and Society 48, 193–216. https://doi.org/10.1007/s11186-019-09345-5

Tracy, S. J. 2010. Qualitative quality: Eight ‘‘big-tent’’ criteria for excellent qualitative research. Qualitative Inquiry, 16, 837-851

Treiblmaier, H. and Beck, R. 2019. Business transformation though blockchain Vol I. Switzerland: Palgrave Macmillan, 125-127

Tsatsou, P. et al., 2010. Towards a taxonomy for regulatory issues in a digital business ecosystem in the EU. Journal of Information Technology 25, 288-307. https://doi.org/10.1057/jit.2009.22

Tushman M. and Anderson P. 1986. Technological discontinuities and organizational environments. Administrative Science Quarterly 31(3): 439–465. doi: 10.2307/2392832

Uca, N et al. 2017. The Effect of Trust in Supply Chain on the Firm Performance through Supply Chain Collaboration and Collaborative Advantage. Journal of Administrative Sciences. 15. 215-230.

Ulrich, K. and Eppinger, S. 2003. Product Design and Development. IFTH EDITION Published by McGmw-Hill,

Vargo, S. L. and Lusch, R. F. 2016. Institutions and axioms: an extension and update of service dominant logic. Journal of the Academy of Marketing Science, 44(1), 5–23. https://doi.org/10.1007/s11747-015-0456-3

Vargo, S. L. and Lusch, R. F. 2004. Evolving to a new dominant logic. Journal of Marketing 68, 1–17. https://doi.org/10.1509/jmkg.68.1.1.24036

Vaughan, S. 2013. Elite and elite-lite interviewing: Managing our industrial legacy. In A. Franklin & P. Blyton (Eds.), Researching sustainability: A guide to social science methods, practice and engagement pp. 105–119. London, U.K.: Routledge.

Velu, C. 2018. BMI Research Programme, Mimeo, Institute for Manufacturing, Department of Engineering, University of Cambridge

Vidgen, R and Wang, X. 2006. From business process management to business process ecosystem. Journal of Information Technology, 21, 262-271. https://doi.org/10.1057/palgrave.jit.2000076

Voelpel, S.C. et al. 2004. The wheel of business model reinvention: how to reshape your business model to leapfrog competitors. Journal of Change Management 4 (3),

Wang, Y., Chen, C. and Zghari-Sales, A. 2020. Designing a blockchain enabled supply chain. International Journal of Production Research. 59. 1-26. 1

Watanabe, et al., 2004. A substitution orbit model of competitive innovations. Technological Forecasting and Social Change 71, 365-390. https://doi.org/10.1007/978-3-540-89272-4_4

Weiss, R. S. 1994. Learning from strangers: The art and method of qualitative interview studies. New York: The Free Press

Weking, J. et al. 2020. The impact of blockchain technology on business models – a taxonomy and archetypal patterns. Electronic Markets. 30. 285–305

Womack, J and Daniel, J.2010. Lean Thinking: Banish Waste and Create Wealth in Your Corporation. pp90-102,

Womack, J., Jones, D.T and Roos, D. 1990. The Machine that Changed the World. New York: Rawson Associates, 1990.

Wook, K.S. 2006. Effects of supply chain management practices, integration and competition capability on performance, Supply Chain Management, Vol. 11 No. 3, pp. 241-248

World Resources Institute. 2000. World Resources 2000-2001: People and ecosystems: The fraying web of life. Report Series. 41p. Retrieved from: http://pubs.wri.org/pubs_pdf.cfm?PubID=3027 Accessed Jan 2022

Wortmann. J.C. 1995. Comparison of information systems for engineer-to-order and make-to-stock situations Computers in Industry, 26 (3), pp. 261-27

Wright, M. 2012. Academic entrepreneurship technology transfer and society: where next? Journal of Technology Transfer 39 (3), 322–334. https://doi.org/10.1007/s10961-012-9286-3

Wirtz, B. et al. 2016. Business Models: Origin, Development and Future Research Perspectives. Long Range Planning. 46.

Xu, M., Chen, X. and Kou, G.2019. A systematic review of blockchain. Financial Innovation Journal 5, 27 doi

Xu, X., et al., 2017. A Taxonomy of Blockchain-Based Systems for Architecture Design. In Proceedings of the 2017 IEEE International Conference on Software Architecture (ICSA), Gothenburg, Sweden, 3–7 April 2017; pp. 243–252. https://doi.org/10.1109/ICSA.2017.33

Yang, B and Burns. N. 2003. Implications of postponement for the supply chain International Journal of Production Research, 41 (9), pp. 2075-2090

Yin, R. K. 1994. Discovering the future of the case study. Method in evaluation research. Evaluation Practice, 15(3), 283-290.

Yli-Huumo, J. D. et al. 2016. Where is current research on blockchain technology? - A systematic review, PLoS One 11 (10) 1–27. https://doi.org/10.1371/journal.pone.0163477

Zachman, J. 1999. A Framework for Information Systems Architecture, IBM Systems Journal, pp. 38(2-3), 454-70, https://doi.org/10.1147/sj.382.0454

Zapfel, G. and Missbauer, H. 1993. New concepts for production planning and control, European Journal of Operational Research, Elsevier, vol. 67(3), pages 297-320.

Zhang, R, Xue, R and Ling L. 2019. Security and Privacy on Blockchain. *ACM Computing Surveys (CSUR)* 52: 1 - 34. https://doi.org/10.1145/3316481

Zhao, J. and Wei. J. 2014. The Coordinating Contracts for a Fuzzy Supply Chain with Effort and Price Dependent Demand. Applied Mathematical Modelling 38 (9-10): 2476–2489.

Zott, C. and Amit. R. 2010. Business model design: An activity system perspective. Long Range Planning, 43(2–3) 216–226.

Zott, C., Raphael, A. and Massa, L. 2011. The Business Model: Recent Developments and Future Research. Journal of Management. 37,