University of the Aegean
Department of Financial and Management Engineering

Εφαρμογές εννοιών λιτής παραγωγής σε περιβάλλον υπηρεσιών (Lean manufacturing concepts in service environments)

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Lean manufacturing concepts in service environments

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Εκτενής Περίληψη Διατριβής

Extended Abstract (in Greek)

1. Εισαγωγή

Ο τομέας των υπηρεσιών κυριαρχεί σήμερα στις παγκόσμιες οικονομίες τόσο όσον αφορά το σχετικό μερίδιο στο Ακαθάριστο Εθνικό Προϊόν (ΑΕΠ) όσο και στην απασχόληση (αριθμός θέσεων εργασίας). Στις Ηνωμένες Πολιτείες (ΗΠΑ) για παράδειγμα, πιθανώς την πιο προηγμένη οικονομία στον κόσμο, πάνω από 85% του ΑΕΠ και της απασχόλησης προήρθε από τις υπηρεσίες (στοιχεία 2007 από Apte *et al.*, 2012). Ωστόσο, παρά την σημασία του τομέα των υπηρεσιών και τις συνεχείς προσπάθειες υποστήριξης των λειτουργιών του μέσω της πληροφορικής, φαίνεται ότι η παραγωγικότητα στον τομέα υστερεί έναντι του τομέα της μεταποίησης. Στις χώρες της Ευρωζώνης για παράδειγμα, ένα μείγμα προηγμένων οικονομιών με διαφορετικά χαρακτηριστικά, η παραγωγικότητα στον τομέα της μεταποίησης είναι σταθερά υψηλότερη σε σχέση με την παραγωγικότητα του τομέα των υπηρεσιών (OECD, 2017).

Επιπλέον, ο έντονος ανταγωνισμός μεταξύ των εταιρειών παροχής υπηρεσιών καθώς και η προσδοκώμενη αύξηση της ζήτησης για υπηρεσίες - λόγω των δημογραφικών αλλαγών και των τεχνολογικής εξελίξεων - καθιστούν την ανάγκη βελτίωσης της παραγωγικότητας στις υπηρεσίες πιο επίκαιρη από ποτέ. Παραδοσιακά, οι οργανισμοί παροχής υπηρεσιών χρησιμοποιούσαν τον παραγωγικό τομέα και τη μεταποίηση (manufacturing) ως πηγή έμπνευσης για τη βελτίωση των λειτουργιών τους. Ως εκ τούτου, η αδιαμφισβήτητη επιτυχία της Toyota Motor Company οδήγησε ακαδημαϊκούς ερευνητές και στελέχη επιχειρήσεων να μελετήσουν το σύστημα παραγωγής της Toyota και τη σχετική τάση του Lean Manufacturing ή «Λιτής Παραγωγής» (ΛΠ εφεξής) σε μια προσπάθεια να αποκωδικοποιήσουν και να μεταφέρουν τις ιδέες, τις στρατηγικές και τις μεθόδους της σε περιβάλλοντα υπηρεσιών. Σήμερα, σχεδόν είκοσι χρόνια μετά την εισαγωγή του όρου Lean Service ή «Λιτής Υπηρεσίας» (ΛΥ εφεξής) από τους Bowen και Youngdahl (1998), εξακολουθούν να υπάρχουν ερωτήματα σχετικά με το εύρος και τους τρόπους εφαρμογής του. Σε αυτή τη διατριβή ρίχνουμε φως σε πτυχές της ακόλουθης ερευνητικής ερώτησης: *σε ποιο βαθμό μπορούν να υιοθετηθούν και να προσαρμοστούν σε περιβάλλοντα παροχής υπηρεσιών ορισμένες σημαντικές έννοιες της ΛΠ.*

Συγκεκριμένα, εξετάζουμε πρώτα τις διαφορές μεταξύ μεταποίησης και υπηρεσιών και τις βασικές προκλήσεις στις λειτουργίες (operations) των υπηρεσιών. Στη συνέχεια, εξετάζουμε την ιστορική εξέλιξη της ΛΠ, των βασικών συνιστωσών της, τα αποτελέσματα από εφαρμογές της καθώς και των πτυχών που κατέστησαν την προσέγγιση αυτή επαναστατική. Τέλος, κάνουμε μια βιβλιογραφική ανασκόπηση των λιτών υπηρεσιών και ταξινομούμε τα αποτελέσματα σε τρεις ενότητες: α) στην καταλληλότητα από θεωρητική σκοπιά της ΛΠ στις υπηρεσίες, β) σε πρακτικές εφαρμογές της ΛΠ σε διάφορους κλάδους και λειτουργίες υπηρεσιών και τέλος γ) στη βιωσιμότητα και συνεχόμενη βελτίωση των πρακτικών της ΛΠ στις υπηρεσίες. Σημειώνουμε ότι η βιβλιογραφική έρευνα είναι εκτεταμένη (δεδομένου του εύρους του αντικειμένου). Συγκεκριμένα χρειάστηκε να διερευνήσουμε τρεις ξεχωριστές περιοχές: η 1η αφορά τον ορισμό, χαρακτηριστικά και διαφορές των υπηρεσιών σε σχέση με τη μεταποίηση, η 2η αφορά τον ορισμό, συνιστώσες και εφαρμογές της λιτής παραγωγής στη μεταποίηση και η 3η αφορά τις εφαρμογές της λιτής παραγωγής στις υπηρεσίες. Ωστόσο η εκτεταμένη βιβλιογραφική επισκόπηση και ανάλυση κρίθηκε απαραίτητη για να εντοπίσουμε τα δέκα κενά στη βιβλιογραφία και να επικεντρώσουμε την παρούσα διατριβή σε τέσσερα από αυτά. Συγκεκριμένα, αποσαφηνίζουμε την ουσία και στόχους της ΛΠ στις υπηρεσίες, παρέχουμε ένα καθολικό πλαίσιο για την ταξινόμηση των υπηρεσιών και τέλος εξετάζουμε τη δυνατότητα εφαρμογής δύο από των πλέον δημοφιλών πρακτικών της ΛΠ σε ένα πολύπλοκο περιβάλλον υπηρεσιών: την ποιότητα στην πηγή (quality at source) και την κυψελοειδή δομή εργασιών (cellular work structures).

Η συνεισφορά μας στη μελέτη των εννοιών της ΛΠ στις υπηρεσίες περιλαμβάνει τους ακόλουθους τομείς:

Στον τομέα της επιστήμης των υπηρεσιών, και ενόψει της έλλειψης κοινώς αποδεκτού πλαισίου για την ταξινόμηση και αξιολόγηση των υπηρεσιών, προτείνουμε μια νέα προσέγγιση, τη Μήτρα Χαρακτηριστικών - Διαδικασιών Υπηρεσιών (ΜΧΔΥ) ή Service Attribute - Process Matrix (SAPM). Η ΜΧΔΥ περιέχει τα πιο γνωστά χαρακτηριστικά ταξινόμησης των υπηρεσιών οργανωμένα σε έξι ξεχωριστές ενότητες, τις επιδράσεις αυτών στις κύριες διαδικασίες καθώς και τις αλληλεξαρτήσεις μεταξύ των χαρακτηριστικών. Με τον τρόπο αυτό, η ΜΧΔΥ παρέχει μια γενική αρχιτεκτονική για το σχεδιασμό υπηρεσιών που μπορεί να χρησιμοποιηθεί ως βάση για τη διερεύνηση της αρθρωτής δομής (modularization) στις υπηρεσίες, ενός τομέα που προσελκύει όλο και μεγαλύτερο ενδιαφέρον.

Στον τομέα της ποιότητας των υπηρεσιών, εισάγουμε ένα νέο θεωρητικό πλαίσιο, τον φαύλο κύκλο προβλημάτων ποιότητας στις λειτουργίες των υπηρεσιών. Μέσω προσομοίωσης ενός τυπικού συστήματος υπηρεσιών δύο σταδίων - της μονάδας που συναλλάσσεται με τον πελάτη και της υποστηρικτικής μονάδας (front-back office) που συναντάμε σε πολλούς οργανισμούς παροχής υπηρεσιών - εξετάζουμε το φαύλο κύκλο προβλημάτων ποιότητας καθώς και τον αντίκτυπο τυπικών πρακτικών για την αντιμετώπιση των προβλημάτων ποιότητας. Το μοντέλο προσομοίωσης και τα σχετικά σενάρια μπορούν να προσαρμοστούν εύκολα για να διερευνήσουν τα προβλήματα ποιότητας (και τις πρακτικές αντιμετώπισή τους) σε άλλα παρόμοια και πιο πολύπλοκα συστήματα εξυπηρέτησης (π.χ. ν-σταδίων).

Στον τομέα των κυψελοειδών δομών εργασίας, βάσει εμπειρικής έρευνας και προσομοίωσης, παρέχουμε μια λεπτομερή ανάλυση της καταλληλότητας και των επιπτώσεων της οργάνωσης συστημάτων παροχής υπηρεσιών σε κυψελοειδείς δομές. Για την εν προκειμένω έρευνα, αναπτύσσουμε ένα μοντέλο προσομοίωσης. Το μοντέλο αυτό ενσωματώνει τις ακόλουθες τρεις πτυχές μέσω των οποίων εκδηλώνεται η συμπεριφορά των εργαζομένων που επηρεάζει την απόδοση του συστήματος εξυπηρέτησης: α) τον τρόπο με τον οποίο οι εργαζόμενοι αντιδρούν στις αλλαγές του φόρτου εργασίας, β) την ευελιξία των εργαζομένων όσον αφορά την αλληλουχία εργασιών που δύνανται να εκτελέσουν και γ) τον τρόπο με τον οποίο οι εργαζόμενοι συνεργάζονται μεταξύ τους. Αυτές οι πτυχές της επαγγελματικής συμπεριφοράς έχουν μελετηθεί στο παρελθόν, αλλά όχι στο πλαίσιο των κυψελοειδών δομών εργασίας.

Τέλος, στον τομέα των ΛΥ, η παρούσα διατριβή παρέχει λεπτομερή καταγραφή των βασικών συστατικών της ΛΠ βάσει βιβλιογραφίας. Συγκεκριμένα, περιλαμβάνει πλήρη κατάλογο των πηγών αναποτελεσματικότητας (σπατάλες) στις υπηρεσίες, των ορισμών, των αρχών, καθώς και των σχετικών πρακτικών και εργαλείων της ΛΠ. Επίσης, εισάγουμε νέο ορισμό των ΛΥ και πραγματοποιούμε πλήρη αξιολόγηση της δυνατότητας εφαρμογής των πρακτικών της ΛΠ στις υπηρεσίες. Η αξιολόγηση αυτή μπορεί να χρησιμοποιηθεί ως εργαλείο υποστήριξης αποφάσεων για την επιτάχυνση του ρυθμού υιοθέτησης και προσαρμογής της ΛΠ σε περιβάλλοντα παροχής υπηρεσιών.

2. Λιτή Παραγωγή στις Υπηρεσίες

Στις παρακάτω ενότητες εξετάζουμε συνοπτικά τη ΛΠ καθώς και τις εφαρμογές αυτής στις υπηρεσίες. Κλείνουμε το παρόν κεφάλαιο εντοπίζοντας δέκα κενά στη βιβλιογραφία των ΛΥ και αναδεικνύουμε αυτά τα οποία αποτελούν το επίκεντρο της παρούσας διατριβής.

Λιτή Παραγωγή

Το Σύστημα Παραγωγής της Toyota (TPS ή Toyota Production System) περιλαμβάνει ένα σύνολο αρχών, στόχων, επιστημονικών τεχνικών και μεθόδων το οποίο δέχτηκε επιρροές από πρωτοπόρους της διοικητικής επιστήμης όπως οι F. Taylor, J. Juran και E. Deming, καθώς και από την Ιαπωνική κουλτούρα, ιστορία και γεωγραφική θέση. Αναπτύχθηκε μετά από μακρόχρονες προσπάθειες τη δεκαετία του ‘50, ως μέσο επίτευξης του στόχου της Ιαπωνικής βιομηχανίας να ανταγωνισθεί επάξια τη Δυτική και, ιδιαίτερα, την Αμερικανική βιομηχανία. Κύριοι εμπνευστές της φιλοσοφίας και της ανάπτυξης του συστήματος παραγωγής της Toyota ήταν οι Toyoda Kiichiro, ιδρυτής της αυτοκινητοβιομηχανίας Toyota, και ο Taiichi Ohno διευθυντής παραγωγής και αρχιμηχανικός της Toyota. Η πρόκληση για τον T. Ohno ήταν ο σχεδιασμός συστήματος παραγωγής το οποίο παράγει διαφορετικά μοντέλα αυτοκινήτων σε περιορισμένους αριθμούς και ανταποκρίνεται στις ιδιαίτερες ιαπωνικές συνθήκες (περιορισμένο κεφάλαιο, μειωμένο προσωπικό, γεωγραφικά αποκλεισμένη και σχετικά περιορισμένη αγορά). Το αποτέλεσμα ήταν, μετά από αρκετές δεκαετίες, ο σχεδιασμός ενός συστήματος παραγωγής το οποίο άλλαξε τις συνθήκες του διεθνούς ανταγωνισμού και ανέδειξε την Toyota, αλλά και την Ιαπωνική βιομηχανία γενικότερα, σε πρωτοπόρο παγκοσμίως (Hopp και Spearman, 2001).

Κεντρική φιλοσοφία της ΛΠ είναι η εξάλειψη οτιδήποτε «περιττού» στην παραγωγική διαδικασία. Συγκεκριμένα, O T. Ohno εισήγε, μεταξύ άλλων, τον όρο «muda» δηλαδή «σπατάλη» ή «περιττό» στα ιαπωνικά (waste στα αγγλικά), ο οποίος αναφέρεται σε οτιδήποτε χρησιμοποιεί πόρους χωρίς να δημιουργεί όφελος και αναγνώρισε εφτά τύπους «σπατάλης» κατά τη διάρκεια της παραγωγικής διαδικασίας, ως εξής (Ohno,1988):

1. Υπέρμετρη παραγωγή (over-production), δηλ. παραγωγή περισσότερη και νωρίτερα από όσο και όταν χρειάζεται ή πριν καν χρειαστεί,
2. Αναμονή (wait time), δηλ. άσκοπη αναμονή μεταξύ δύο ή περισσοτέρων βημάτων στη παραγωγική διαδικασία,
3. Μεταφορά (transportation), δηλ. κάθε άσκοπη μεταφορά, υλικού ή πληροφορίας η οποία δεν υποστηρίζει ευθέως την παραγωγή,
4. Επεξεργασία (over-processing), δηλ. περιττή επεξεργασία η οποία δεν προσθέτει αξία στο προϊόν/ υπηρεσία,
5. Αποθέματα (inventory), δηλ. άσκοπη συγκέντρωση αποθεμάτων τα οποία προορίζονται για περαιτέρω επεξεργασία ή κατανάλωση,
6. Κίνηση (motion), δηλ. οποιαδήποτε περιττή κίνηση η οποία δεν προσθέτει αξία στο προϊόν/υπηρεσία,
7. Ελαττωματικό υλικό (defect) που χρειάζεται επισκευή ή που δεν επιδέχεται περαιτέρω επισκευή.

Ωστόσο, ο εντοπισμός και εξάλειψη οτιδήποτε περιττού στην παραγωγική διαδικασία, δεν είναι καινούργια ιδέα αλλά προϋπάρχει εδώ και εκατό περίπου χρόνια. Το συμπέρασμα πολλών ειδικών (Hopp και Spearman, 2001) είναι ότι η βασική φιλοσοφία της ΛΠ βασίζεται σε κάτι πολύ πιο ουσιώδες από ότι η εξάλειψη των ορατών προβλημάτων στην παραγωγή. Αυτό είναι η μεταβλητότητα (ή ετερογένεια) στις λειτουργίες και συνθήκες της παραγωγής (variability στα αγγλικά ή mura στα ιαπωνικά). Δηλαδή, οτιδήποτε στο σύστημα παραγωγής δεν είναι κανονικό και προβλέψιμο δημιουργεί μεταβολές και αναταράξεις (mura) οι οποίες με τη σειρά τους επιβαρύνουν τους ανθρώπους και τον εξοπλισμό (muri) και τελικά οδηγούν σε σπατάλη πόρων (muda). Προτείνοντας τη μείωση ή εξάλειψη της μεταβλητότητας (εσωτερικής και εξωτερικής) ως κεντρική φιλοσοφία της ΛΠ, αναπτύχθηκε ένα σύνολο στόχων, τεχνικών και μεθόδων το οποίο και παρουσιάζεται συνοπτικά στη συνέχεια. Οι βασικοί άξονες της ΛΠ είναι δύο:

- *«Παραγωγή την κατάλληλη στιγμή»* (Just-in-Time). Ανάλογη με την ιδέα του super market, όπου ο πελάτης είναι σε θέση να βρει στιγμιαία το προϊόν που επιθυμεί, στόχος είναι η ανάπτυξη παραγωγικού περιβάλλοντος στο οποίο κάθε σταθμός εργασίας προμηθεύεται τα απαραίτητα υλικά για την εκτέλεση μιας κατεργασίας, στον επιθυμητό χρόνο και στην επιθυμητή ποσότητα από τον προηγούμενο σταθμό. Αυτό απαιτεί ένα περιβάλλον το οποίο λειτουργεί ομαλά, χωρίς διακοπές, καθώς αυτές μπορούν να διαταράξουν ολόκληρο το σύστημα παραγωγής
- *Έξυπνη αυτοματοποίηση* (*Autonomation*, ή *automation with a human touch*) δηλαδή μηχανές οι οποίες μπορούν να α) παράγουν αυτόματα, έτσι ώστε ένας εργαζόμενος να μπορεί να λειτουργεί ταυτόχρονα πολλαπλές μηχανές, και β) επιτελούν διάγνωση (αυτόνομα) τυχόν προβλημάτων και σταματούν τη λειτουργία τους (αυτόματα), έτσι ώστε να αποφευχθεί η παραγωγή ελλαττωματικών προϊόντων.

Επιπρόσθετα, για την υλοποίηση της *«παραγωγής την κατάλληλη στιγμή»* απαιτούνται συγκεκριμένες προϋποθέσεις οι οποίες επιτυγχάνονται με διάφορες πρακτικές. Αναφέρουμε τις σημαντικότερες:

- *Εξομάλυνση παραγωγής (level production)* μέσω: α) προγραμματισμού των απαιτήσεων σε μικρότερες υποπεριόδους και β) ομοιόμορφης αλληλουχίας στην παραγωγή. Συγκεκριμένα, κατά το πρώτο βήμα, κατανέμονται οι απαιτήσεις ζήτησης μιας περιόδου αναλογικά σε υποπεριόδους της περιόδου αυτής. Στο δεύτερο βήμα η ημερήσια παραγωγή μετασχηματίζεται σε αλληλουχία παραγωγής εντός της ημέρας με βάση τις αναλογίες ζήτησης τελικών προϊόντων. Προφανώς για να επιτευχθεί η αλληλουχία στην παραγωγή διαφορετικών προϊόντων απαιτούνται συχνές αλλαγές, οι οποίες με τη σειρά τους απαιτούν ελάχιστους χρόνους προετοιμασίας.
- *Μείωση χρόνων προετοιμασίας (setup time reduction)* μέσω διαχωρισμού των εργασιών προετοιμασίας σε εσωτερικές (απαιτούν διακοπή της λειτουργίας ενός σταθμού εργασίας) και εξωτερικές (δηλ. δεν απαιτούν διακοπή). Εφόσον οι εργασίες προετοιμασίας έχουν διαχωριστεί, το επόμενο βήμα είναι η μετατροπή όλο και περισσότερων εργασιών προετοιμασίας από εσωτερικές σε εξωτερικές, για παράδειγμα εξαλείφοντας τις ρυθμίσεις (με την βοήθεια ειδικών συσκευών, αισθητήρων κλπ.). Άλλος τρόπος μείωσης του χρόνου προετοιμασίας είναι η εξάλειψη της ίδιας της ανάγκης για προετοιμασία (με τη βοήθεια ενιαίου σχεδιασμού των προϊόντων, ή μέσω χρήσης παράλληλων μηχανών, η κάθε μία από τις οποίες έχει προετοιμασθεί για συγκεκριμένο προϊόν).

- *Πολλαπλή κατάρτιση εργαζομένων (cross skilling).* Εργαζόμενοι οι οποίοι είναι ικανοί να χειρίζονται πολλαπλούς σταθμούς εργασίας - και συνεπώς, να μετακινούνται σε διαφορετικές θέσεις εργασίας βάσει φόρτου εργασίας - συνεισφέρουν στη διατήρηση ομαλής παραγωγής. Τυπικές τεχνικές αναβάθμισης των δεξιοτήτων των εργαζομένων περιλαμβάνουν την ανάθεση εργασιών σε αυτούς (σε καθημερινή βάση εφόσον εκπαιδευτούν) που αντιστοιχούν σε όλους τους σταθμούς εργασίας ενός τμήματος του εργοστασίου. Ως αποτέλεσμα α) κάθε εργαζόμενος είναι σε θέση να χειρίζεται ένα μικρό αριθμό διαφορετικών μηχανών, και β) αναπτύσσεται και καλλιεργείται εργασιακό περιβάλλον στη συνεχή βελτίωση του οποίου συμβάλλουν ενεργητικά οι εργαζόμενοι.
- *Κυψελοειδής χωροταξία (cellular layout).* Η λειτουργική χωροταξία, στην οποία λειτουργικά πανομοιότυποι σταθμοί εργασίας βρίσκονται στον ίδιο χώρο του εργοστασίου (π.χ. τμήμα τόρνων, τμήμα φρεζών, κλπ.), δεν είναι η πλέον κατάλληλη, καθότι α) δεν χρησιμοποιούνται πλήρως οι πολλαπλές δεξιότητες των εργαζομένων και β) κάθε φάση του φασεολογίου απαιτεί και μετακίνηση μεταξύ τμημάτων. Ως προτιμητέα χωροταξία αναδεικνύεται η οργάνωση παραγωγής σε κυψέλες (cells). Κάθε κυψέλη αποτελείται από λειτουργικά ανόμοιους σταθμούς εργασίας (π.χ. ένα τόρνο, μία φρέζα) οι οποίοι όμως παράγουν προϊόντα παρόμοιων χαρακτηριστικών. Τα προϊόντα αυτά παράγονται (σχεδόν) εξ ολοκλήρου εντός της κυψέλης στην οποία ανήκουν με αποτέλεσμα να ελαχιστοποιείται η μετακίνηση υλικών και να απλοποιείται ο προγραμματισμός και έλεγχος παραγωγής, καθότι μειώνεται η πολυπλοκότητα του συστήματος, το οποίο πλέον αποτελείται από μικρά, αυτόνομα (ή ημιαυτόνομα) υπο-συστήματα.
- *Διοίκηση ολικής ποιότητας (Total Quality Management – TQM).* Όπως αναφέρθηκε προηγουμένως, ένα αποτελεσματικό σύστημα παραγωγής απαιτεί ομαλή και αδιάκοπη ροή της παραγωγικής διαδικασίας. Τυχόν προβλήματα ποιότητας ενδέχεται να διακόπτουν αυτή τη ροή δημιουργώντας σημαντικότατα εμπόδια στην παραγωγή. Συνεπώς, τεχνικές οι οποίες βοηθούν στο να εντοπίζονται άμεσα τα ελαττωματικά προϊόντα αλλά και η πηγή τους είναι αναπόσπαστο κομμάτι της ΛΠ. Τέτοιες τεχνικές περιλαμβάνουν σχετικά απλά εργαλεία (στατιστικός έλεγχος ποιότητας ή Statistical Process Control - SPC, σχεδιασμός πειραμάτων ή Design of Experiments - DOE, κύκλοι ποιότητητας ή Quality Circles) σε συνδυασμό με την ενεργητική συμμετοχή των εργαζομένων στην ανάλυση και επίλυση προβλημάτων.

- *Έλξη (Pull) και τεχνική Kanban*. Πέρα από τις προηγούμενες πρακτικές, για την ομαλή λειτουργία της παραγωγής απαιτείται το κατάλληλο σύστημα ελέγχου της ροής των υλικών (ειδών). Η ΛΠ βασίστηκε στην ιδέα της έλξης (pull), σύμφωνα με την οποία οι εντολές δεν απελευθερώνονται στην παραγωγή με βάση συγκεκριμένο χρονοπρόγραμμα (schedule), αλλά κατόπιν έγκρισης η οποία βασίζεται στην κατάσταση (state) του εργοστασίου. Με άλλα λόγια, σε ένα σύστημα *έλξης* (pull) το έναυσμα παραγωγής δίδεται από τη ζήτηση. Μόλις ένα είδος αφαιρείται από το τελικό απόθεμα, ο τελευταίος σταθμός ειδοποιεί τον προηγούμενο σταθμό στο φασεολόγιο να αντικαταστήσει τα υλικά που μόλις χρησιμοποιήθηκαν για την παραγωγή του είδους. Αυτή η διαδικασία επαναλαμβάνεται έως τον αρχικό σταθμό εργασίας στο φασεολόγιο, ο οποίος ειδοποιεί την αποθήκη υλικών (ή ημιετοίμων) να τον τροφοδοτήσει με τα απαραίτητα υλικά. Η υλοποίηση του παραπάνω συστήματος γίνεται με ένα σύστημα καρτών (kanban), οι οποίες εξουσιοδοτούν την διακίνηση των υλικών από τον ένα σταθμό εργασίας στον επόμενο, ελέγχοντας έτσι το ύψος των αποθεμάτων και αποφεύγοντας οποιαδήποτε συσσώρευση τους λόγω διακοπών στην παραγωγή.
- *Ανάπτυξη Προμηθευτών*. Τέλος, η λειτουργία του συστήματος ΛΠ απαιτεί την ομαλή ροή και εκτός εταιρείας. Αυτό προϋποθέτει την ανάπτυξη των σχέσεων μεταξύ εταιρείας και προμηθευτών. Αυτό πρακτικά περιλαμβάνει τρεις πτυχές: *Πρώτον*, η εταιρεία θα πρέπει να επιλέξει ένα συγκεκριμένο αριθμό προμηθευτών με τους οποίους θα αναπτύξει μακροχρόνιες συνεργασίες και συμβόλαια αμοιβαίας ωφέλειας. Αυτό συνεπάγεται μείωση του διαχειριστικού κόστους των προμηθειών και δυνατότητα στενότερης συνεργασίας για την επίτευξη κοινών στόχων. *Δεύτερον*, η εταιρεία θα πρέπει να μεταφέρει τη γνώση που έχει αποκομίσει καθώς και τις απαραίτητες προδιαγραφές των απαιτούμενων προϊόντων και υπηρεσιών στους προμηθευτές της ώστε να μην σπαταλώνται χρόνος και πόροι στον έλεγχο των προμηθευόμενων υλικών και υπηρεσιών. Οι προμηθευτές με τους οποίους η εταιρεία τελικά θα επιλέξει να συνεργαστεί πρέπει να είναι απολύτως συμμορφωμένοι και πιστοποιημένοι σύμφωνα με τα πρότυπα της εταιρείας. Επίσης, απαιτούνται κοινές προσπάθειες για μείωση του κόστους και τη βελτίωση της ποιότητας σε όλα τα στάδια της μεταξύ τους συνεργασίας. *Τρίτον*, οι προμηθευτές θα πρέπει να προσαρμόσουν το πρόγραμμα παράδοσης των προϊόντων τους και να γίνουν αδιάσπαστα μέρη της παραγωγής της εταιρείας διενεργώντας συχνές παραδόσεις.

Οι παραπάνω πρακτικές, καθώς και άλλες κάτω από το πρίσμα της ΛΠ, είχαν σημαντικό αντίκτυπο στον τομέα της μεταποίησης και στον επιστημονικό κλάδο της διοίκησης λειτουργιών (Operations Management) καθώς αποτέλεσαν αντικείμενο εκτεταμένης εφαρμογής και έρευνας σε όλους σχεδόν τους παραγωγικούς κλάδους (Hopp και Spearman, 2001). Ωστόσο, παρά την εκτεταμένη έρευνα και εφαρμογή της ΛΠ φαίνεται, από πηγές της βιβλιογραφίας, ότι η ΛΠ δεν είχε πάντα τα επιθυμητά αποτελέσματα ή τα αρχικά ευνοϊκά αποτελέσματα δεν ήταν εύκολο να διατηρηθούν. Όπως υποστηρίζει ο Hopp (2013), «*μια δίκαιη εκτίμηση είναι ότι η ΛΠ μπορεί να παράγει θεαματικά αποτελέσματα, αλλά αυτό είναι σπάνιο*». Οι πιθανές αιτίες περιλαμβάνουν α) *τεχνικούς περιορισμούς*, όπως το κόστος υιοθέτησης των ενδεδειγμένων πρακτικών ή η επέκταση τους σε μη - επαναλαμβανόμενα περιβάλλοντα παραγωγής, β) *ανθρώπινους παράγοντες*, όπως η δέσμευση και η ενεργή συμμετοχή της διοίκησης και των εργαζομένων στην υιοθέτηση της ΛΠ και τέλος γ) *δυσκολίες κατανόησης* της πραγματικής ουσίας της ΛΠ. Ίσως, η σημαντικότερη κληρονομιά της ΛΠ είναι η διορατικότητα που προσφέρει στην δυναμική του εργοστασίου και στη διαχείριση των σχέσεων μεταξύ των διαθέσιμων πόρων: αποθέματος, χρόνου παραγωγής, και διαθέσιμων ανθρώπινων πόρων (Hopp και Spearman, 2001).

Εφαρμογές Λιτής Παραγωγής στις υπηρεσίες

Σήμερα ακόμη και παραδοσιακοί κλάδοι υπηρεσιών, όπως η υγεία και οι χρηματοπιστωτικές υπηρεσίες, έχουν εκτεθεί σε μερικές από τις έννοιες της ΛΠ και έχουν πειραματιστεί με τουλάχιστον μία πρωτοβουλία ΛΠ τα τελευταία είκοσι χρόνια (Hopp, 2013). Ωστόσο, όπως συμβαίνει στην περίπτωση της μεταποίησης, η μεταφορά και η προσαρμογή εννοιών της ΛΠ εκτός της αυτοκινητοβιομηχανίας δεν είναι απλή υπόθεση για πολλούς λόγους.

Πρώτον, οι υπηρεσίες είναι πολύ διαφορετικές, με διακριτικά επιχειρησιακά χαρακτηριστικά και καλύπτουν ένα ευρύ φάσμα τομέων από την υγεία έως τις χρηματοοικονομικές υπηρεσίες και τις υπηρεσίες τουρισμού. *Δεύτερον*, οι υπηρεσίες περιλαμβάνουν μοναδικά στοιχεία που δεν εντοπίζονται ούτε αντιμετωπίζονται στη μεταποίηση, όπως η συμμετοχή των πελατών στην παραγωγική διαδικασία, η υψηλή εξάρτηση τους αποτελέσματος της υπηρεσίας από τους εργαζόμενους, καθώς και ο άυλος χαρακτήρας των υπηρεσιών. *Τρίτον*, οι υπηρεσίες έχουν εγγενώς ισχυρή μεταβλητότητα λόγω αυτών των μοναδικών στοιχείων καθώς και των απρόβλεπτων διακυμάνσεων που τυπικά εμφανίζονται σε αλυσίδες υπηρεσιών, στις οποίες πολλαπλοί επαγγελματίες από διαφορετικά πεδία και οντότητες παρεμβαίνουν για να ανταποκριθούν στο αίτημα ενός πελάτη (Harvey, 2016). Ως εκ τούτου, η δυνατότητα μεταφοράς των εννοιών της ΛΠ σε συστήματα υπηρεσιών είναι περίπλοκη και δεν μπορεί να στηριχθεί αποκλειστικά στη σχετική έρευνα που έχει πραγματοποιηθεί στον τομέα της μεταποίησης.

Συγκεκριμένα, αξιολογώντας τέσσερα βασικά χαρακτηριστικά των υπηρεσιών (συμμετοχή των πελατών στην παραγωγική διαδικασία, υπηρεσίες εντάσεως εργασίας, φυσικά αποθέματα ως μέρους του πακέτου υπηρεσιών, και ταυτόχρονη παραγωγή και κατανάλωση) σε έξι διαφορετικές λειτουργίες (σχεδιασμός υπηρεσιών, διαχείριση πόρων, προγραμματισμός και διαχείριση ουρών αναμονής, διαχείριση της απόδοσης, και διαχείριση και οργάνωση των ανθρώπινων πόρων), καταλήγουμε στο συμπέρασμα ότι οι πάροχοι υπηρεσιών αντιμετωπίζουν πολύ διαφορετικές προκλήσεις από ότι στη μεταποίηση. Για παράδειγμα, καθώς η συμμετοχή των πελατών στην παροχή των υπηρεσιών αυξάνεται, αυξάνεται επίσης η ανάγκη για πιο ευέλικτες διαδικασίες και περίπλοκα συστήματα για την αξιολόγηση της ποιότητας και της απόδοσης των υπηρεσιών. Οι πάροχοι υπηρεσιών αντιμετωπίζουν επίσης διαφορετικές προκλήσεις όσον αφορά τη διαχείριση των ανθρώπινων πόρων, όπως για παράδειγμα στην αναβάθμιση δεξιοτήτων και στον έλεγχο απόδοσης ιδιαίτερα στις επαγγελματικές υπηρεσίες. Τα αποτελέσματα υποδεικνύουν επίσης ότι στην περίπτωση άυλων υπηρεσιών (δηλ. υπηρεσίες που δεν περιλαμβάνουν φυσικό απόθεμα) οι διαθέσιμοι πόροι για να αντιμετωπιστούν οι διακυμάνσεις ζήτησης είναι οι ανθρώπινοι πόροι καθώς και ο χρόνος απόκρισης (ενώ στη μεταποίηση υφίστανται επιπλέον και τα αποθέματα).

Από την πλευρά της πρακτικής εφαρμογής, οι πρώτες ερευνητικές προσπάθειες αποκάλυψαν ότι οι διάφοροι κλάδοι υπηρεσιών χρησιμοποιούν παραδοσιακά μερικές από τις έννοιες της ΛΠ. Για παράδειγμα, όλες οι επιχειρήσεις παροχής υπηρεσιών έχουν κάποιο βαθμό τυποποίησης στις δραστηριότητές τους ή εφαρμόζουν πρακτικές με παρόμοιους στόχους με εκείνους της ΛΠ. Ενδεικτικά, τα συστήματα κρατήσεων χρησιμοποιούνται εδώ και χρόνια στους κλάδους του τουρισμού και αερομεταφορών για να εξομαλύνουν τη ζήτηση. Αυτό είναι αντίστοιχο με τις πρακτικές εξομάλυνσης της παραγωγής στη μεταποίηση.

Επίσης, παρόλο που πολλές μελέτες έχουν αναφέρει σημαντικά οφέλη, αυτές συχνά στερούνται εμπειρικής τεκμηρίωσης ή επικεντρώνονται αποκλειστικά στην εφαρμογή επιλεγμένων πρακτικών σε ορισμένες λειτουργίες και τομείς (π.χ., τμήμα επειγόντων περιστατικών στις υπηρεσίες υγείας). Το σημαντικότερο είναι ότι δεν υπήρξε συστηματική διερεύνηση των παραγόντων που επηρεάζουν τη γενίκευση της εφαρμογής της ΛΠ στις υπηρεσίες (Costa και Filho, 2016).

Οι περισσότεροι ερευνητές συμφωνούν ότι η ΛΠ είναι εφαρμόσιμη και μπορεί να έχει σημαντικό αντίκτυπο στις υπηρεσίες με επαναλαμβανόμενες λειτουργίες, μεγάλο αριθμό πελατών και φυσικά αποθέματα ως μέρους του πακέτου υπηρεσιών. Επιπλέον, υποστηρίζεται ότι ενώ οι αρχές της ΛΠ είναι σχετικές σε οποιοδήποτε περιβάλλον υπηρεσιών, η εφαρμογή τους δεν μπορεί να γίνει με τον ίδιο τρόπο σε κάθε περίπτωση αλλά θα πρέπει να προσαρμοστεί στις ιδιαιτερότητες κάθε υπηρεσίας. Ωστόσο, στη βιβλιογραφία δεν υπάρχει πλήρης εικόνα σχετικά με το τι πρέπει να προσαρμοστεί με βάση τα χαρακτηριστικά του περιβάλλοντος και της επιχείρησης (Seddon *et al.*, 2011).

Σημαντικότερες ελλείψεις και κρίσιμες περιοχές εστίασης των ΛΥ

Στις επόμενες παραγράφους συνοψίζουμε δέκα τομείς που, κατά την άποψη του συγγραφέα, αξίζουν περαιτέρω διερεύνηση όσον αφορά την εφαρμογή των αρχών και των πρακτικών της ΛΠ στις υπηρεσίες.

1. *Ανάγκη για συστηματικότερη και περεταίρω έρευνα στις υπηρεσίες έντασης πληροφορίας και γνώσης*. Απαιτείται μεγαλύτερη σαφήνεια όσον αφορά τον ορισμό και την ουσία των ΛΥ στους τομείς αυτούς καθώς και επέκταση της έρευνας στις επαγγελματικές υπηρεσίες (Prashar και Antony, 2018) ή σε αλυσίδες υπηρεσιών (βλ. Harvey, 2016). Αυτό είναι μία έλλειψη και ευκαιρία για περαιτέρω έρευνα την οποία διερευνούμε στην παρούσα διατριβή μέσο ενός νέου ορισμού των ΛΥ καθώς και μέσω προσομοίωσης σε πολύπλοκα σχετικά περιβάλλοντα.
2. *Οργάνωση της τεράστιας ποικιλίας των διάφορών υπηρεσιών*. Η απουσία μιας κοινώς αποδεκτής προσέγγισης για την ταξινόμηση των υπηρεσιών αποτελεί χαρακτηριστική έλλειψη στον τομέα της επιστήμης των υπηρεσιών. Τα χαρακτηριστικά ταξινόμησης των υπηρεσιών θα μπορούσαν να χρησιμοποιηθούν ως εργαλεία εντοπισμού των προσαρμογών που απαιτούνται για την εφαρμογή της ΛΠ σε διαφορετικά περιβάλλοντα υπηρεσιών. Στην παρούσα διατριβή εισάγουμε ένα νέο πλαίσιο ταξινόμησης των υπηρεσιών.

Τα παρακάτω σημεία είναι και αυτά σημεία περεταίρω διερεύνησης, αλλά συνάμα υποδηλώνουν *τους τομείς εστίασης* οι οποίοι απαιτούνται για την επίτευξη των ΛΥ.

3. *Εστίαση στην τεχνολογία*. Η τεχνολογία ενώ είχε καθοριστικό ρόλο για τη διαμόρφωση και επιτυχία της ΛΠ (π.χ. μέσω μηχανών *έξυπνης αυτοματοποίησης*, ή ευέλικτων μηχανών ικανών να επεξεργάζονται διαφορετικούς τύπους προϊόντων), δεν ερευνήθηκε επαρκώς στην σχετική ακαδημαϊκή βιβλιογραφία. Περαιτέρω ο ρόλος της

τεχνολογίας στην εφαρμογή της ΛΠ στις υπηρεσίες δεν έχει διερευνηθεί διεξοδικά δεδομένου του βαθμού εξάρτησης των υπηρεσιών από την τεχνολογία και υπό το πρίσμα της λεγόμενης τέταρτης βιομηχανικής επανάστασης. Για παράδειγμα, οι πρόσφατες εξελίξεις στην τεχνολογία και Τεχνητή Νοημοσύνη (Artificial Intelligence), αναμένεται να συνεισφερουν στην αντικατάσταση της ανθρώπινης εργασίας σε μεγάλη κλίμακα στις υπηρεσίες. Συνεπώς, ο ρόλος της Τεχνητής Νοημοσύνης στις λιτές υπηρεσίες είναι ένας τομέας ο οποίος χρήζει περαιτέρω διερεύνησης.

4. *Εστίαση στην ολιστική προσέγγιση*. Η ολιστική, συστημική προσέγγιση που προτείνεται από τις ΛΥ δεν έχει ερευνηθεί επαρκώς στην υφιστάμενη βιβλιογραφία. Ένα τυπικό παράδειγμα αφορά τις δομές κυψελοειδούς εργασίας, στις οποίες οι δραστηριότητες ενσωματώνονται στην ίδια δομή με βάση την ομοιότητα της διαδικασίας. Υπάρχουν περιορισμένες αναφορές των συνθηκών που ευνοούν τη χρήση των κυψελοειδών δομών στις υπηρεσίες, μία έλλειψη που στοχεύουμε να διερευνήσουμε στην παρούσα διατριβή.
5. *Εστίαση στην καινοτομία*. Η πρόκληση για τα στελέχη της Toyota ήταν η παραγωγή διαφορετικών αυτοκινήτων υψηλής ποιότητας σε περιορισμένες ποσότητες με τον πιο αποτελεσματικό τρόπο. Οι καινοτόμες αυτές πρακτικές της ΛΠ μεταμόρφωσαν ολόκληρη την αυτοκινητοβιομηχανία. Ωστόσο, υπάρχουν πολύ λίγες αναφορές για καινοτομίες που επήλθαν ως αποτέλεσμα της υλοποίησης της ΛΠ στις υπηρεσίες.
6. *Εστίαση στις επιχειρησιακές λεπτομέρειες και προκλήσεις του εκάστοτε συστήματος υπηρεσιών*. Οι εκάστοτε επιχειρησιακές λεπτομέρειες και η κατανόηση τους, καθώς και οι ιδιαίτερες προκλήσεις του κάθε κλάδου υπηρεσιών, δεν έχουν προσελκύσει ιδιαίτερο ερευνητικό ενδιαφέρον. Ως εκ τούτου, θα ήταν χρήσιμη η διερεύνηση των σχετικών επιχειρησιακών λεπτομερειών και προκλήσεων κάθε υπηρεσίας και ιδιαίτερα εκείνων που σχετίζονται με την εμπειρία του πελάτη πριν, κατά και μετά της χρήσης μιας υπηρεσίας.
7. *Εστίαση στη «έξυπνη» διαχείριση των εν εξελίξει εργασιών και κατανομή των πόρων*. Ορισμένες υπηρεσίες διαθέτουν περιορισμένους ή διαφορετικούς πόρους για τη διαχείριση της μεταβλητότητας (διακύμανση ζήτησης, απαιτήσεις πελατών, κλπ.). Για παράδειγμα οι επαγγελματικές υπηρεσίες δε διαθέτουν αποθέματα παρά μόνο το χρόνο, το ανθρώπινο δυναμικό και την ποιότητα (με την έννοια ότι η ποιότητα μπορεί να προσαρμοστεί ανάλογα της ζήτησης). Η σημασία επομένως του ελέγχου των εν εξελίξει εργασιών (Work in Progress ή WIP) ως μέσο για την εξεύρεση του βέλτιστου

(δηλ. χαμηλότερο κόστος για συγκεκριμένο χρόνο απόκρισης και ποιότητα) συνδυασμού διαθέσιμων πόρων δεν έχει διερευνηθεί διεξοδικά στις υπηρεσίες.

8. *Εστίαση στην ευελιξία*. Η ευελιξία των πόρων, και ιδιαίτερα των ανθρώπινων, είναι ένα από τα κύρια σημεία εστίασης της ΛΥ. Ωστόσο, υπάρχουν δύο τομείς στις υπηρεσίες που χρήζουν περαιτέρω έρευνας. Η πρώτη αφορά τις πρακτικές διαχείρισης γνώσης και εκπαίδευσης, παρακίνησης, μέτρησης απόδοσης και αμοιβής των εργαζομένων σε επαγγέλματα εντάσεως γνώσεως. Το δεύτερο αφορά το βαθμό και τον τρόπο στον οποίο μπορεί να χρησιμοποιηθεί η τυποποίηση μέσω πρότυπων διαδικασιών και πρακτικών αρθρωτής δομής (modularization).
9. *Εστίαση στην ποιότητα έναντι της ποσότητας*. Η ποιότητα είναι κεντρικό σημείο εστίασης στις υπηρεσίες δεδομένου ότι α) τα προβλήματα ποιότητας είναι ο μεγαλύτερος τύπος αναποτελεσματικότητας στις υπηρεσίες, β) είναι δύσκολο να καθοριστεί, δηλ. μεταβάλλεται βάσει των προσδοκιών και εμπειριών του εκάστοτε πελάτη και γ) αποτελεί μέσο διαχείρισης της αυξημένης ζήτησης από τους εργαζομένους, δηλ. οι εργαζόμενοι χαλαρώνουν τα κριτήρια ποιότητας για να ανταπεξέλθουν στη ζήτηση. Επομένως, η επιλογή των κριτηρίων ποιότητας και των πρακτικών που τα διασφαλίζουν χρήζει περεταίρω διερεύνησης. Στην παρούσα διατριβή εξετάζουμε την επίδραση α) των προβλημάτων ποιότητας στις λειτουργίες των υπηρεσιών και β) τα οφέλη και μειονεκτήματα ορισμένων από τις σύνηθες πρακτικές που χρησιμοποιούνται για να τα αντιμετωπίσουν.
10. *Εστίαση στη συνεχή βελτίωση*. Τέλος, οι οργανισμοί παροχής υπηρεσιών προκειμένου να βελτιώνονται συνεχώς πρέπει να αναπτύξουν τις εξής ικανότητες, οι οποίες και χρήζουν διερεύνησης. Η πρώτη αναφέρεται στις πρακτικές παρακίνησης του ανθρώπινου δυναμικού σε δραστηριότητες και έργα συνεχόμενους βελτίωσης. Το δεύτερο αφορά τις βέλτιστες πρακτικές για την υλοποίηση και μετάβαση σε μια ΛΥ (π.χ. κατευθυνόμενη έναντι αυτενεργής αλλαγής, όπως προτείνεται από τους Seddon *et al.*, 2011) λαμβάνοντας υπόψη παράγοντες όπως η αδιάκοπη λειτουργία, τα διασκορπισμένα δίκτυα, ο χρόνος και το κόστος.

Στις επόμενες ενότητες συνοψίζεται η βασική ερευνητική συνεισφορά της παρούσας διατριβής.

3. Ταξινόμηση υπηρεσιών

Συνοπτική ανασκόπηση σχετικής βιβλιογραφίας

Η συνεχόμενη ενίσχυση του ρόλου του τομέα των υπηρεσιών στις οικονομίες των προηγμένων χωρών, έχει ωθήσει πολλούς ερευνητές από διαφορετικά πεδία στην προσπάθεια κατανόησης του χαρακτήρα των υπηρεσιών. Κοινό στοιχείο αναφοράς στους περισσότερους ορισμούς για τις υπηρεσίες είναι η άποψη ότι οι υπηρεσίες αποτελούν δραστηριότητες ή διαδικασίες στις οποίες «*το κυρίαρχο αντικείμενο μετασχηματισμού είναι ο άνθρωπος (πελάτης), με την πληροφορία να ακολουθεί και τέλος, σε μικρότερο βαθμό, τα υλικά συστατικά, ενώ στη μεταποίηση και κατασκευές το κυρίαρχο αντικείμενο επεξεργασίας είναι τα υλικά*» (Moris and Johnston, 1987).

Με βάση αυτή τη διάκριση, έχουν προταθεί από πολλαπλούς ερευνητές μια σειρά *βασικών ιδιοτήτων ή χαρακτηριστικών* που προσδιορίζουν τις υπηρεσίες σε σχέση με τα προϊόντα. Για παράδειγμα, η *συμμετοχή του πελάτη* στη δημιουργία και προσφορά της υπηρεσίας καθώς και ο βαθμός στον οποίο ο πελάτης μπορεί *να παρεμβαίνει και να αλλάζει* ορισμένες πτυχές της υπηρεσίας. Επίσης, η εξάρτηση της υπηρεσίας από τον *εκάστοτε πάροχό* (εξυπηρετητή) της όσον αφορά την ποιότητα, το κόστος και την ταχύτητα ολοκλήρωσης της υπηρεσίας. Αυτή η στενή αλληλεπίδραση πελάτη-πάροχου υπηρεσίας αποκαλύπτει ένα άλλο σημαντικό χαρακτηριστικό των υπηρεσιών: το γεγονός ότι ο πελάτης (καταναλωτής) είναι πολλές φορές και *προμηθευτής* απαραίτητος για την παροχή της υπηρεσίας. Επίσης, το αποτέλεσμα ή προϊόν μια υπηρεσίας πολλές φορές είναι *άυλο*, το οποίο αν δεν καταναλωθεί τη στιγμή που είναι διαθέσιμο *χάνεται για πάντα* (εφόσον δεν μπορεί να συσσωρευθεί σε μορφή αποθέματος).

Δεδομένου ότι πολλές από αυτές τις ιδιότητες ισχύουν και στη μεταποίηση - λόγω τεχνολογικής προόδου και κυρίως με την εξάπλωση χρήσης του διαδικτύου και άλλων τεχνολογιών αυτοεξυπηρέτησης (self-service) - πολλοί ερευνητές, προσπάθησαν να ερμηνεύσουν τις υπηρεσίες ταξινομώντας αυτές σε ομοειδή κατηγορίες βάσει κοινών χαρακτηριστικών ή ιδιοτήτων. Οι περισσότεροι προσδιορίζουν τις υπηρεσίες βάσει δύο συνήθως χαρακτηριστικών (π.χ. πολυπλοκότητα και όγκος συναλλαγών), τα οποία που οδηγούν στη δημιουργία μιας μήτρας (ή πίνακα) δύο επί δύο με κάθε άξονα να αντιστοιχεί σε κάθε ένα από τα δύο χαρακτηριστικά. Οι τύποι υπηρεσιών τοποθετούνται είτε σε κάθε τεταρτημόριο (π.χ. Maister και Lovelock, 1982) είτε στη διαγώνιο της μήτρας (π.χ., Kellogg και Nie, 1995) και ανάλογα με τη θέση τους (στο κάθε τεταρτημόριο είτε σε κάθε θέση στη διαγώνιο) αντιστοιχούν διαφορετικές προκλήσεις, ευκαιρίες και συνεπώς στρατηγικές για της διατήρηση της ανταγωνιστικής τους θέσης.

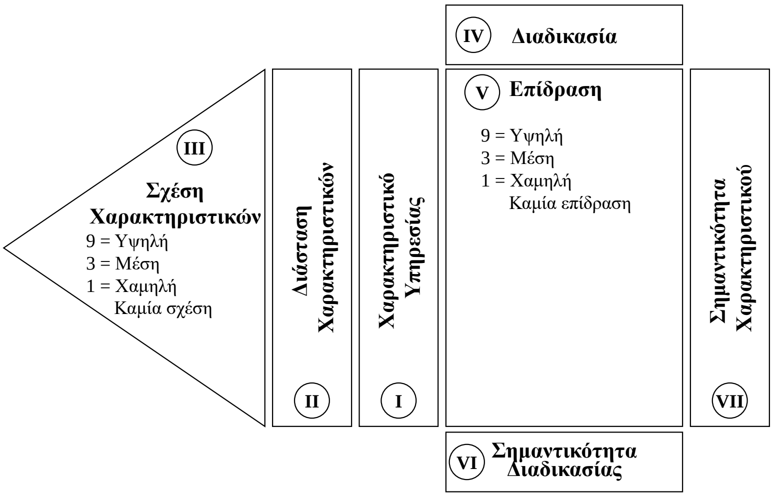
Παρόλη τη χρησιμότητα τους, πολλά μοντέλα ταξινόμησης υπηρεσιών έχουν υποβληθεί σε κριτική. Για παράδειγμα, τα χαρακτηριστικά δεν είναι πάντα εύκολο να προσδιοριστούν βάσει αντικειμενικών κριτηρίων, έχουν περιορισμένη εστίαση χωρίς να παρέχουν ολοκληρωμένη εικόνα για τις υπηρεσίες και δεν έχουν δοκιμαστεί εμπειρικά. Επιπλέον, ο μεγάλος και διαφορετικός αριθμός ιδιοτήτων και κατά συνέπεια μοντέλων ταξινόμησης (περίπου 40), υποδεικνύουν τη σημαντική *ετερογένεια* ή *μεταβλητότητα* (variability) που χαρακτηρίζει τις υπηρεσίες, η οποία με τη σειρά της δημιουργεί αβεβαιότητα σχετικά με το χρόνο, την ποιότητα και το κόστος της υπηρεσίας.

Η Μήτρα Χαρακτηριστικών - Διαδικασιών Υπηρεσιών

Η Μήτρα Χαρακτηριστικών - Διαδικασιών Υπηρεσιών (ΜΧΔΥ) που προτείνεται στην παρούσα διατριβή συνδέει τις ιδιότητες ή χαρακτηριστικά των υπηρεσιών με τις διαδικασίες του κύκλου ζωής της υπηρεσίας. Κάθε ένα από τα χαρακτηριστικά έχει διαφορετική επίδραση στην κάθε διαδικασία, επομένως η ΜΙΔΥ υποστηρίζει τον εντοπισμό των επιδράσεων του εκάστοτε χαρακτηριστικού στις κύριες διαδικασίες των υπηρεσιών χρησιμοποιώντας ένα τυποποιημένο πλαίσιο.

Η διάταξη της ΜΧΔΥ περιλαμβάνει επτά μέρη (Σχήμα Ε.1), τα οποία περιγράφονται παρακάτω. Ο κατακόρυφος άξονας (μέρος Ι στο Σχήμα Ε.1) αντιπροσωπεύει τα χαρακτηριστικά ταξινόμησης των υπηρεσιών όπως καταγράφηκαν από ανασκόπηση της σχετικής βιβλιογραφίας (Πίνακα Β.1 του Παραρτήματος Β). Τα χαρακτηριστικά έχουν ομαδοποιηθεί σε έξι διαστάσεις (μέρος ΙΙ):

1. *Κίνητρα προμήθειας της υπηρεσίας από τον πελάτη*, σχετιζόμενα με τον ίδιο τον πελάτη και τα κίνητρα που κατευθύνουν τις επιλογές του,
2. *Πρακτικές προμήθειας της υπηρεσίας από τον πελάτη*, σχετιζόμενα με τον τρόπο με τον οποίο ο πελάτης ασκεί την αγοραστική συμπεριφορά του,
3. *Τρόποι παροχής υπηρεσιών,* σχετιζόμενα με τις μεθόδους που χρησιμοποιούνται για την παροχή της υπηρεσίας
4. *Τρόποι παραγωγής της υπηρεσίας,* σχετιζόμενα με τις μεθόδους που χρησιμοποιούνται για την παραγωγή της υπηρεσίας,
5. *Χαρακτηριστικά αποτελέσματος υπηρεσίας,* σχετιζόμενα με τη φύση του τελικού αποτελέσματος της υπηρεσίας, και
6. *Στοιχεία διοίκησης υπηρεσιών,* σχετιζόμενα με τα σημεία που πρέπει να εξετάσει η διοίκηση κατά τη λήψη αποφάσεων σχετικά με την εκτέλεση της υπηρεσίας.



Σχήμα Ε.1: Διάταξη της Μήτρας Χαρακτηριστικών - Διαδικασιών Υπηρεσιών

Τα χαρακτηριστικά των υπηρεσιών έχουν εντοπιστεί από τη βιβλιογραφία επομένως δεν είναι ανεξάρτητα, αλλά οι σχέσεις τους αναλύονται, στο μέρος III της ΜΧΔΥ. Ο οριζόντιος άξονας (IV) αντιπροσωπεύει τις κύριες διαδικασίες στον κύκλο ζωής των υπηρεσιών. Τις διαδικασίες τις επιλέξαμε από το Πλαίσιο Κατάταξης Διαδικασιών του Αμερικανικού Κέντρου Παραγωγικότητας και Ποιότητας (APQC, 1992) και είναι οι ακόλουθες:

1. *Ανάπτυξη του οράματος και της στρατηγικής,*
2. *Σχεδιασμός και ανάπτυξη προϊόντων και υπηρεσιών,*
3. *Προμήθεια και πώληση προϊόντων και υπηρεσιών,*
4. *Παροχή προϊόντων ή υπηρεσιών,*
5. *Διαχείριση της εξυπηρέτησης πελατών,*
6. *Ανάπτυξη και διαχείριση ανθρώπινου κεφαλαίου,*
7. *Διαχείριση της πληροφορικής και της γνώσης,*
8. *Διαχείριση οικονομικών πόρων.*

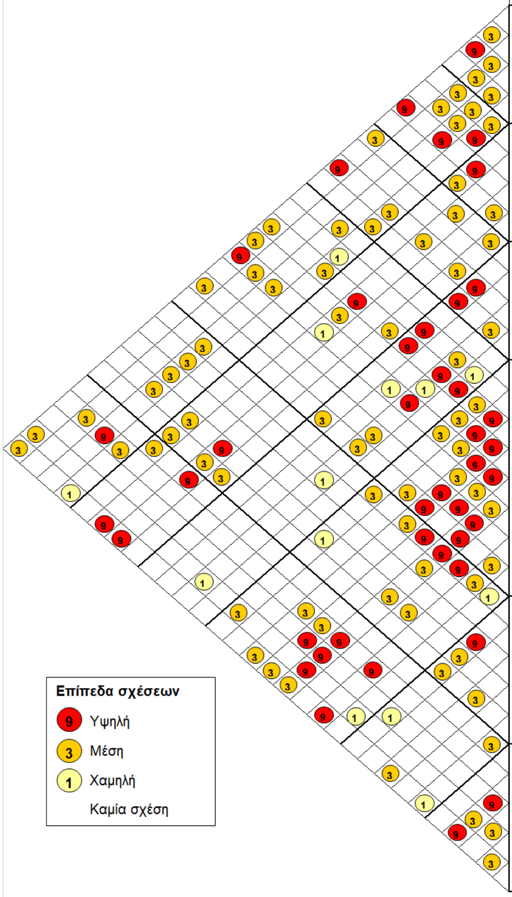
Η επίδραση κάθε χαρακτηριστικού στη κάθε διαδικασία έχει αξιολογηθεί στο μέρος V της ΜΧΔΥ. Η αξιολόγηση βασίστηκε στη σχετική βιβλιογραφία, ενώ στις περιπτώσεις όπου δεν υπήρχαν σχετικές αναφορές η αξιολόγηση συμπληρώθηκε βάσει της εμπειρίας των συντελεστών της παρούσας έρευνας στις υπηρεσίες. Τέλος, η συνολική βαθμολογία κάθε στήλης αποκαλύπτει τη σχετική επίδραση όλων των χαρακτηριστικών στην αντίστοιχη διαδικασία (μέρος VI), ενώ η συνολική βαθμολογία κάθε σειράς αποκαλύπτει τη σχετική σημασία κάθε χαρακτηριστικού κατά τη διάρκεια ολόκληρου του κύκλου ζωής μιας υπηρεσίας (VII).

Σημαντικότερα χαρακτηριστικά και σύνθετες διαδικασίες

Η ΜΧΔΥ παρουσιάζεται ολοκληρωμένη στο Σχήμα Ε.2. Όπως αναφέρθηκε, η τιμή του κάθε στοιχείου c_{ij} του μέρους VI της ΜΧΔΥ κατατάσσει την σημαντικότητα του χαρακτηριστικού i για τη διαδικασία j σε μια κλίμακα 1-3-9 (τυπική κλίμακα αξιολόγησης κριτηρίων στην έρευνα σχεδιασμού ποιότητας). Αθροίζοντας τις βαθμολογίες κάθε σειράς, μπορεί κανείς να προσδιορίσει τα πιο σημαντικά χαρακτηριστικά σε ολόκληρο τον κύκλο ζωής της υπηρεσίας. Στην τελευταία στήλη της ΜΙΔΥ, φαίνεται ότι τα πέντε πιο σημαντικά χαρακτηριστικά είναι: ο βαθμός επαφής με τον πελάτη (4.3), ο βαθμός τυποποίησης της υπηρεσίας (4.5), το κανάλι παροχής υπηρεσιών (3.3), η επίδραση του πελάτη (4.4) το είδος του πελάτη (1.1).

Αθροίζοντας τις βαθμολογίες αντίστοιχα σε κάθε στήλη του ΜΧΔΥ, μπορεί κανείς να προσδιορίσει την πολυπλοκότητα κάθε διαδικασίας στον κύκλο ζωής της υπηρεσίας. Μια διαδικασία η οποία επηρεάζεται έντονα από πολλά χαρακτηριστικά υπηρεσιών, θεωρείται περίπλοκη, αφού οι διαχειριστές πρέπει να εξετάσουν όλα αυτά τα χαρακτηριστικά στο σχεδιασμό, τον προγραμματισμό και την εκτέλεση των σχετικών δραστηριοτήτων. Σύμφωνα με αυτό το κριτήριο, οι τρεις πιο σύνθετες διαδικασίες είναι: 2.0 Σχεδιασμός και ανάπτυξη προϊόντων και υπηρεσιών, 3.0 Προμήθεια και πώληση προϊόντων και υπηρεσιών και 4.0 Πώληση ή παροχή προϊόντων ή υπηρεσιών.

Η συνεισφορά της ΜΧΔΥ στο σχεδιασμό ενός συστήματος υπηρεσιών έγκειται στον εντοπισμό των χαρακτηριστικών με τις σημαντικότερες επιπτώσεις σε ολόκληρο τον κύκλο ζωής της υπηρεσίας με σκοπό τη διαχείριση της πολυπλοκότητα της κάθε διαδικασίας. Επιπλέον, η ΜΧΔΥ παρέχει μια γενική αρχιτεκτονική για το σχεδιασμό υπηρεσιών που μπορεί να χρησιμοποιηθεί ως βάση για τη διερεύνηση της αρθρωτής δομής (modularization) στις υπηρεσίες. Τέλος, η ΜΧΔΥ παρέχει ένα συστηματικό τρόπο για τον εντοπισμό και επανεξέταση των χαρακτηριστικών εκείνων που οφείλονται για την ετερογένεια ή μεταβλητότητα (variability) της υπηρεσίας.



Διαστάσεις	Διαδικασία / Χαρακτηριστικά Υπηρεσιών	1.0 1. Ανάπτυξη του οράματος και της στρατηγικής	2.0 2. Σχεδιασμός και ανάπτυξη προϊόντων και υπηρεσιών	3.0 Προμήθεια και πώληση προϊόντων και υπηρεσιών	4.0 Παροχή προϊόντων και υπηρεσιών	5.0 5. Διαχείριση της εξυπηρέτησης πελατών	6.0 6. Ανάπτυξη και διαχείριση ανθρώπινου κεφαλαίου	7.0 7. Διαχείριση της πληροφορικής και της γνώσης	8.0 8. Διαχείριση οικονομικών πόρων	Συνολική βαθμολογία
1.0 Κίνητρα προμήθειας της υπηρεσίας	1. Τύπος πελάτη (ιδιώτης/ εταιρεία)	9	3	9	9	3	9	3		45
	2. Αντιλαμβανόμενο ρίσκο από τον πελάτη		9	9		3	1			22
	3. Σημασία υπηρεσίας για τον πελάτη	3	9	9	3	3	1	9		37
	4. Αγοραστική ευκολία		9	9	3		1			22
2.0 Πρακτικές προμήθειας της υπηρεσίας	1. Δέσμευση πελάτη		3	9	3	9	3			27
	2. Ανάγκη φυσικής παρουσίας πελάτη		9	3	9	9	9			39
	3. Διακυμάνσεις ζήτησης		3	3	9	3	1			19
	4. Τύπος σχέσης πελάτη με πάροχο υπηρεσίας (συνεχόμενη/ ανά περίπτωση)		9	3	3	3	9	3	1	31
3.0 Τρόποι παροχής υπηρεσιών	1. Σημεία επαφής πελάτη με πάροχο υπηρεσίας		3	3	9	9	9			33
	2. Τύπος παράδοσης υπηρεσίας		3	9	3	9	9			33
	3. Κανάλι παράδοσης της υπηρεσίας	9	9	9	9	3	3	3	3	48
	4. Κανόνες προτεραιοποίησης	3	9	3	9	9				33
4.0 Τρόποι παραγωγής υπηρεσίας	1. Αντικείμενο επεξεργασίας		3	9	9	3	3	3		30
	2. Άμεσος πάροχος της υπηρεσίας (άνθρωπός/ μηχανές)		3	9	9	3	9	3		36
	3. Βαθμός επαφής με τον πελάτη	9	9	9	9	9	9			54
	4. Επίδραση πελάτη στην υπηρεσία	9	9	3	9	9	9			48
	5. Βαθμός τυποποίησης της υπηρεσίας	9	9	9	9	3	9	3		51
	6. Εστίαση σε προϊόν ή υπηρεσία		3	9	9	3	9			33
	7. Βαθμός χρήσης της κρίσης προσωπικού		9	3	9	9	9	3		42
	8. Εστίαση στην 1η ή στη 2η υποστηρικτική γραμμή		3		9	9	9			30
5.0 Χαρακτηριστικά αποτελέσματος	1. Βαθμός απτότητας (άυλο)		9	9	9	1	3	3		34
	2. Ατομικές ή μαζικές υπηρεσίες		3	9		1		3		16
	3. Ιδιοκτησία υπηρεσίας		3	9	1					13
	4. Μεμονωμένη υπηρεσία ή πακέτο υπηρεσιών		9	9	9					27
	5. Χρονική διάρκεια ωφελειών της υπηρεσίας		9	9	3	3				24
6.0 Στοιχεία διοίκησης υπηρεσιών	1. Βαθμός στον οποίο η προσφορά είναι περιορισμένη	3	3	9	9	9	9			42
	2. Βαθμός διοικητικού ελέγχου	3	9	3	9	9	3			36
	3. Αντιλαμβανόμενο ρίσκο από την εταιρεία	3	9	9	3	9	3	3	3	42
	4. Κόστος παραγωγής και συναλλαγών		9	3	9			9	3	33
	5. Βαθμός ρυθμιστικών περιορισμών	3	9	1	3	9	1		1	27
	Συνολική βαθμολογία	54	195	190	187	149	131	45	11	

Σχήμα Ε.2: Η Μήτρα Χαρακτηριστικών - Διαδικασιών Υπηρεσιών

4. Ποιότητα υπηρεσιών και επιπτώσεις στις λειτουργίες των υπηρεσιών

Συνοπτική ανασκόπηση σχετικής βιβλιογραφίας

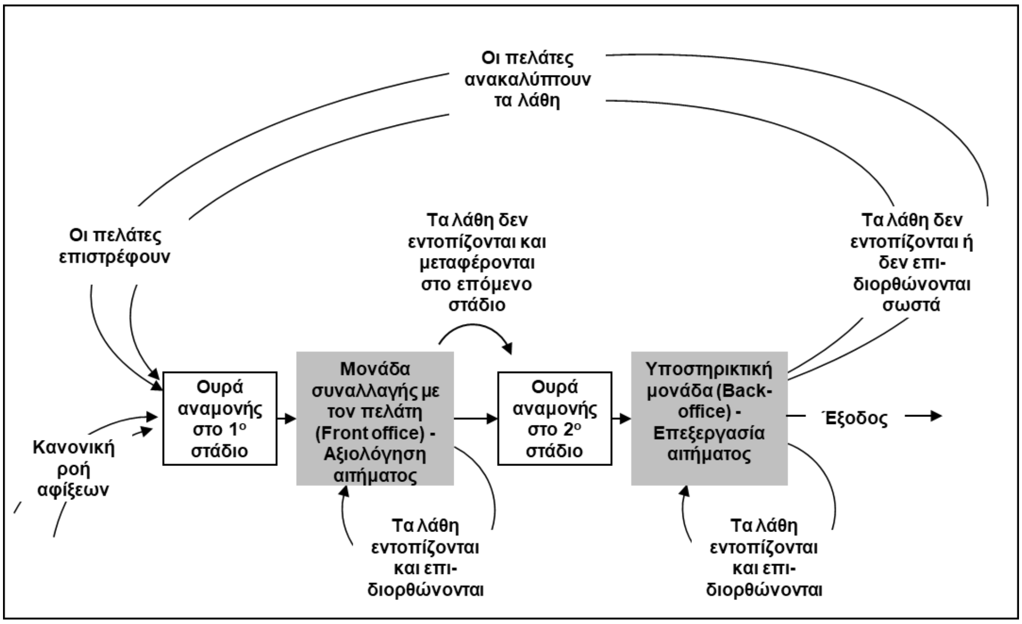
Όπως αναφέραμε παραπάνω, ένα σημαντικό πεδίο εστίασης της ΛΠ είναι η μείωση της μεταβλητότητας (ή ετερογένειας) στις λειτουργίες και συνθήκες της παραγωγής. Στις υπηρεσίες, πέρα από την εγγενή μεταβλητότητα - λόγω της ισχυρή εξάρτησης της υπηρεσίας από τον πελάτη και τον εκάστοτε εργαζόμενο (ή ομάδα εργαζομένων) που παρέχει(-ουν) την υπηρεσία - σημαντικό αίτιο μεταβλητότητας σχετίζεται με αστοχίες ή προβλήματα ποιότητας (χρησιμοποιούμε εναλλασσόμενα τους όρους αστοχίες, λάθη, παραλείψεις, αποτυχίες, κλπ. για να περιγράψουμε τα προβλήματα ποιότητας). Οι αστοχίες αυτές μπορούν να προκύψουν σε τρία στάδια στον κύκλο ζωής των υπηρεσιών.

Το πρώτο στάδιο αφορά το *σχεδιασμό των υπηρεσιών*, δηλαδή ελλείψεις στην ενσωμάτωση στο σχεδιασμό εκείνων των χαρακτηριστικών που υποστηρίζουν την ποιότητα, ευελιξία και ταχύτητα της υπηρεσίας. Το δεύτερο σχετίζεται με τη *διαχείριση του συστήματος υπηρεσιών*, δηλαδή με αστοχίες που προκύπτουν ως αποτέλεσμα των τακτικών και βραχυπρόθεσμων αποφάσεων της διοίκησης, όπως η στελέχωση, ο προγραμματισμός και η διαχείριση της απόδοσης. Το τρίτο στάδιο αφορά *την εκτέλεση των υπηρεσιών*, δηλ. αστοχίες που συμβαίνουν κατά την εκτέλεση της υπηρεσίας είτε εξαιτίας του παρόχου της υπηρεσίας (π.χ. σφάλματα κατά τη διάγνωση ή την παράδοση της υπηρεσίας,) ή του πελάτη (π.χ. λάθη κατά την προετοιμασία).

Προφανώς λάθη ή παραλείψεις κατά το σχεδιασμό μιας υπηρεσίας σχετίζονται με αστοχίες κατά την εκτέλεση της, ιδίως όταν αυτές επαναλαμβάνονται. Στην παρούσα διατριβή εξετάζουμε τον αντίκτυπο των προβλημάτων ποιότητας τα οποία προκύπτουν κατά την *εκτέλεση* (τρίτο στάδιο) και κατά τη *διαχείριση* (δεύτερο στάδιο) της υπηρεσίας. Συγκεκριμένα, μέσω ενός μοντέλου προσομοίωσης σε περιβάλλον παροχής χρηματοοικονομικών υπηρεσιών, διερευνούμε τον αντίκτυπο: α) κρίσιμων *παραγόντων ποιότητας* κατά την εκτέλεση της υπηρεσίας και β) διαφόρων τυπικών *διοικητικών πρακτικών* για την αντιμετώπιση προβλημάτων ποιότητας.

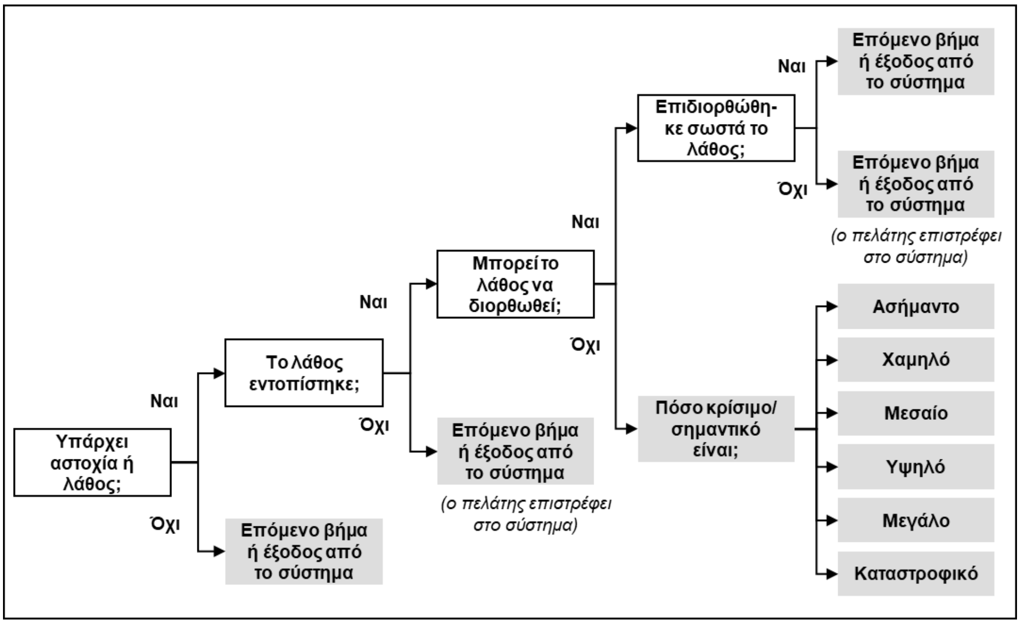
Συνοπτική παρουσίαση μοντέλου προσομοίωσης και πειραματικής προσέγγισης

Το μοντέλο προσομοίωσης βασίζεται σε ένα απλό, αλλά τυπικό, σύστημα υπηρεσιών, το οποίο περιλαμβάνει δύο στάδια που αντιπροσωπεύουν τις λειτουργίες της μονάδας που συναλλάσσεται με τον πελάτη (front-office) και της υποστηρικτικής μονάδας (back-office) (Σχήμα Ε.3). Για λόγους απλοποίησης, το σύστημα παρέχει μόνο έναν τύπο υπηρεσίας και κάθε στάδιο εκτελεί ένα μέρος της διαδικασίας. Δηλαδή, ο πελάτης εισέρχεται στο πρώτο στάδιο και περιμένει στην αρχική ουρά αναμονής. Μόλις ελευθερωθεί κάποιος εργαζόμενος (εξυπηρετητής), ο πελάτης υποβάλει το αίτημα του το οποίο εκτελείται από τον εξυπηρετητή. Στη συνέχεια το αίτημα προωθείται στο δεύτερο στάδιο. Ομοίως, μόλις το προσωπικό της υποστηρικτικής μονάδας γίνει διαθέσιμο, εκτελεί τις εναπομείναντες εργασίες και με την ολοκλήρωσή τους το αίτημα εξέρχεται του συστήματος.



Σχήμα Ε.3: Απεικόνιση μοντέλου προσομοίωσης για την μελέτη της ποιότητας στις υπηρεσίες

Λάθη μπορούν να προκύψουν σε κάθε στάδιο της διαδικασίας, τα οποία εάν εντοπιστούν κατά τη διάρκεια της επεξεργασίας διορθώνονται επί τόπου, ενώ εάν δεν εντοπιστούν μεταφέρονται στο επόμενο στάδιο. Εκεί ομοίως, υπάρχει η πιθανότητα να εντοπιστούν (οπότε διορθώνονται) ενώ εάν δεν εντοπιστούν τότε υπάρχει η πιθανότητα να ανακαλυφθούν από τον πελάτη. Σε αυτήν την περίπτωση, ο πελάτης θα επιστρέψει στην αρχική ουρά του συστήματος για να υποβάλει εκ νέου το αίτημα κ.ο.κ. Όπως αναφέραμε, εφόσον το πρόβλημα εντοπίζεται ενώ το αίτημα είναι εντός συστήματος εξυπηρέτησης, τότε θα υποβληθεί για διόρθωση (rework). Εάν όμως δεν μπορεί να διορθωθεί τότε οδηγεί αυτόματα σε αποζημίωση του πελάτη (χρηματική απώλεια). Τέλος, κατά τη διάρκεια της διόρθωσης, υπάρχει εξίσου η πιθανότητα λάθους (δηλ. να μη διορθωθεί σωστά), το οποίο θα οδηγήσει σε επανάληψη ολόκληρου του κύκλου. Η παραπάνω λογική παρουσιάζεται στο Σχήμα Ε.4. Το σχήμα παριστάνει το δέντρο των παραμέτρων ποιότητας και των πιθανών αποτελεσμάτων τους όσον αφορά τα σφάλματα και τη διόρθωση τους. Το σχήμα μας βοηθά να εντοπίσουμε τους σημαντικότερους παράγοντες ποιότητας οι οποίοι θα μελετηθούν μέσω της μεθόδου του Σχεδιασμού Πειραμάτων (Design of Experiments - DOE) (Montgomery, 2005).



Σχήμα Ε.4: Δέντρο παραμέτρων ποιότητας υπηρεσιών και πιθανών αποτελεσμάτων

Α. Παράγοντες προβλημάτων ποιότητας υπηρεσιών

Όπως αναφέραμε, πρώτος στόχος της παρούσας έρευνας είναι η διερεύνηση των επιπτώσεων των παραγόντων ποιότητας στην εκτέλεση της υπηρεσίας και γενικά στο σύστημα υπηρεσιών. Οι πιο σημαντικοί παράγοντες ποιότητας στη βιβλιογραφία καθώς και τα επίπεδα που χρησιμοποιούμε κατά τη διεξαγωγή των πειραμάτων (low – high) παρουσιάζονται στον πίνακα Ε.1. Οι δείκτες που χρησιμοποιήσαμε για να αξιολογήσουμε τις επιδράσεις των παραπάνω παραγόντων στην απόδοση του συστήματος υπηρεσιών περιλαμβάνουν: το συνολικό χρόνο (cycle time-CT), τις εργασίες σε εξέλιξη (work in progress-WIP), το χρόνο αναμονής (queue waiting time-QT), τη χρήση ανθρώπινων πόρων (utilization-U), την ικανοποίηση πελάτη (customer satisfaction-CS), και τις χρηματικές απώλειες (financial loss-FL).

Πίνακας Ε.1: Παράγοντες και επίπεδα του πλήρους-παραγοντικού (full factorial) πειράματος

Παράγοντες (Factors)	Περιγραφή (Description)	Επίπεδα (Level)	
		Χαμηλό (Low)	Υψηλό (High)
Α. Ποσοστό Λάθους (Failure rate)	Η πιθανότητα διενέργειας λάθους κατά την εκτέλεση μιας εργασίας	5%	15%
Β. Ποσοστό Εντοπισμού Λάθους (Failure to Detect Rate)	Η πιθανότητα το λάθος να εντοπιστεί πριν το αίτημα (ή ο πελάτης) εξέλθει από το σύστημα	15%	35%
Γ. Ποσοστό Ικανότητας Διόρθωσης Λάθους (Inability to Rework Rate)	Η πιθανότητα το λάθος να μπορεί να διορθωθεί	5%	15%
Δ. Ποσοστό Λανθασμένης	Η πιθανότητα το λάθος να διορθωθεί σωστά χωρίς περεταίρω επεξεργασία	5%	15%

Παράγοντες (Factors)	Περιγραφή (Description)	Επίπεδα (Level)	
		Χαμηλό (Low)	Υψηλό (High)
Διόρθωσης Λάθους (Incorrect Rework Rate)			
Ε. Στάδιο Διόρθωσης (Rework stage)	Πρακτική «εξολοκλήρου» (single) επαναληπτικής επεξεργασίας, δηλ. για τη διόρθωση ενός λάθους απαιτείται η εξαρχής επεξεργασία από όλα τα στάδια της διαδικασίας και πρακτική διόρθωσης «πολλαπλών» σταδίων (multiple), δηλ. το αίτημα μπορεί να διορθωθεί όπου εντοπιστεί χωρίς να απαιτείται επανάληψη ολόκληρης της διαδικασίας	Πρακτική διόρθωσης πολλαπλών σταδίων (Multiple)	Πρακτική εξολοκλήρου επαναληπτικής επεξεργασίας (Single)

Βάσει των παραπάνω παραγόντων και επιπέδων σχεδιάσαμε ένα 2^5 πλήρες παραγοντικό πείραμα με 32 διαφορετικούς συνδυασμούς μεταξύ των παραγόντων. Για κάθε συνδυασμό διεξήχθησαν δύο πειραματικές διεργασίες (64 κύκλοι συνολικά), προκειμένου να αναλυθεί η ανάλυση διακύμανσης (analysis of variance-ANOVA). Η περίοδος προσομοίωσης ήταν 30 εργάσιμες ημέρες, οκτώ ώρες ημερησίως (οκτάωρη βάρδια). Τα λογισμικά Arena (11.0) και Minitab (15) χρησιμοποιήθηκαν για την ανάπτυξη του μοντέλου προσομοίωσης και στατιστική επεξεργασία των αποτελεσμάτων, αντίστοιχα.

Β. Διοικητικές πρακτικές αντιμετώπισης προβλημάτων ποιότητας στις υπηρεσίες

Όπως αναφέραμε, δεύτερος στόχος της παρούσας έρευνας είναι η διερεύνηση του αντίκτυπου των τυπικών διοικητικών πρακτικών για την αντιμετώπιση προβλημάτων ποιότητας. Οι τρεις διοικητικές πρακτικές που εξετάζουμε, οι ορισμοί και τα χαρακτηριστικά τους παρουσιάζονται στον Πίνακα Ε.2.

Πίνακας Ε.2: Διοικητικές πρακτικές για την αντιμετώπιση προβλημάτων ποιότητας

Πρακτική (Practice)	Περιγραφή (Description)
Βασικό σενάριο (Base Case)	Αυτό είναι το πείραμα αναφοράς στο οποίο όλοι οι παράγοντες παίρνουν τις υψηλές τους τιμές (βάσει Πίνακα Ε.1) για να αντικατοπτρίζουν ένα υπερφορτωμένο σύστημα εξυπηρέτησης. Η μέθοδος της διόρθωσης πολλαπλών σταδίων έχει επιλεγεί, αφού θεωρήθηκε η πιο ρεαλιστική
Επέκταση δυναμικότητας (Add Capacity)	Σύμφωνα με αυτή την πρακτική, το δυναμικό του συστήματος εξυπηρέτησης ενισχύεται με την προσθήκη νέου (αλλά λιγότερο έμπειρου) προσωπικού. Υπολογίσαμε αύξηση της δυναμικότητας κατά 25% (1 πρόσθετος υπάλληλος ανά στάδιο). Για να αντικατοπτρίσουμε το χαμηλότερο επίπεδο εμπειρίας του νέου προσωπικού, η μεταβλητότητα του χρόνου εργασίας αυξήθηκε από NORM (7, 3.5) σε NORM (7, 7).
Απόκριση («καταδίωξη») ζήτησης (Chase Demand)	Αυτή η πρακτική επιδιώκει την αύξηση της παραγωγικότητας, αυξάνοντας την ταχύτητα επεξεργασίας για να ανταπεξέλθει στην αυξημένη ζήτηση. Σε αυτή την περίπτωση, ο χρόνος της διαδικασίας έχει μειωθεί κατά ένα επιθετικό 20%. Ωστόσο, η μεταβλητότητα της διαδικασίας έχει επίσης αυξηθεί από NORM (7, 3.5) σε NORM (5.6, 5.6).
Διόρθωση λαθών εκτός βασικής γραμμής (Off-line processing of failures)	Σε αυτή την πρακτική έχει εισαχθεί ένας νέος σταθμός διόρθωσης λαθών ανά στάδιο επεξεργασίας, με αποτέλεσμα την αύξηση του δυναμικού κατά 25% (ένα πρόσθετο μέλος ανά σταθμό), το οποίο είναι αφιερωμένο στην διόρθωση λαθών εκτός κύριας διαδικασίας (off-line). Και πάλι, για να αντικατοπτρίσουμε την χαμηλότερη εμπειρία των νέων μελών του προσωπικού, υποθέτουμε ότι η μεταβλητότητα του χρόνου εργασίας έχει αυξηθεί από NORM (7, 3.5) σε NORM (7, 7).

Ο Πίνακας Ε.3 συνοψίζει τα επίπεδα των παραγόντων που χρησιμοποιούνται για τη μελέτη των τυπικών παρεμβάσεων της διοίκησης. Η απόδοση κάθε διοικητικής πρακτικής ή παρέμβασης συγκρίνεται με την απόδοση του βασικού σεναρίου.

Πίνακας Ε.3: Παράγοντες και τιμές των διοικητικών πρακτικών για την αντιμετώπιση προβλημάτων ποιότητας

Παράγοντες (Factors)	Βασικό σενάριο (Base Case)	Επέκταση δυναμικότητας (Add Capacity)	Απόκριση («καταδίωξη») ζήτησης (Chase Demand)	Διόρθωση λαθών εκτός βασικής γραμμής (Off-line processing of failures)
Ρυθμός αφίξεων (arrival rate)	1 αίτημα ανά 3 λεπτά			
Αριθμός εξυπηρετητών (number of servers)	8	10	8	10
Χρόνος επεξεργασίας (process time per stage)	ΚΑΝΟΝΙΚΗ (7, 3.5)*	ΚΑΝΟΝΙΚΗ (7, 7)*	ΚΑΝΟΝΙΚΗ (5.6, 5.6)*	ΚΑΝΟΝΙΚΗ (7, 7)*
Α. Ποσοστό Λάθους (Failure rate)	15%			
Β. Ποσοστό Εντοπισμού Λάθους (Failure to Detect Rate)	35%			
Γ. Ποσοστό Ικανότητας Διόρθωσης Λάθους (Inability to Rework Rate)	15%			
Δ. Ποσοστό Λανθασμένης Διόρθωσης Λάθους (Incorrect Rework Rate)	15%			
Ε. Στάδιο Διόρθωσης (Rework stage)	Multiple			

*Σημείωση: ΚΑΤΑΝΟΜΗ (ΜΕΣΗ ΤΙΜΗ, ΤΥΠΙΚΗ ΑΠΟΚΛΙΣΗ)

Αποτελέσματα προσομοίωσης

Α. Επίδραση παραγόντων προβλημάτων ποιότητας στις υπηρεσιών

Η σύνοψη των σημαντικότερων παραγόντων και των αλληλεπιδράσεων τους στους επιλεγμένους δείκτες απόδοσης παρουσιάζεται στον Πίνακα Ε.4, ενώ τα κυριότερα συμπεράσματα συνοψίζονται στις επόμενες παραγράφους. Σημειώνεται ότι τα στοιχεία του Πίνακα Ε.4 βασίζονται στην ανάλυση διακύμανσης (ANOVA) των σημαντικότερων παραγόντων προβλημάτων ποιότητας του Πίνακα Ε.1 (Παράρτημα C).

Πίνακας Ε.4: Στατιστικά σημαντικοί παράγοντες (επίπεδο σημαντικότητας α=0.05)

	Παράγοντες (Factors)	Συνολικός Χρόνος (Cycle Time)	Εργασίες σε εξέλιξη (WIP)	Χρόνος αναμονής (Waiting Time)	Χρήση ανθρ. πόρων (Utiliza-tion)	Ικανο-ποίηση πελάτη (Customer Satisfa-ction)	Χρηματι-κές απώλειες (Financial Impact)
Κύρι ες	Α. Ποσοστό Λάθους (Failure rate)	√	√	√	√	√	√

	Παράγοντες (Factors)	Συνολικός Χρόνος (Cycle Time)	Εργασίες σε εξέλιξη (WIP)	Χρόνος αναμονής (Waiting Time)	Χρήση ανθρ. πόρων (Utiliza-tion)	Ικανο-ποίηση πελάτη (Customer Satisfa-ction)	Χρηματι-κές απώλειες (Financial Impact)
	Β. Ποσοστό Εντοπισμού Λάθους (Failure to Detect Rate)	√	√	√		√	
	Γ. Ποσοστό Ικανότητας Διόρθωσης Λάθους (Inability to Rework Rate)	√	√	√		√	√
	Δ. Ποσοστό Λανθασμένης Διόρθωσης Λάθους (Incorrect Rework Rate)					√	
	Ε. Στάδιο Διόρθωσης (Rework stage)	√	√	√	√	√	
Αλληλεπιδράσεις (2–Way interactions)	Α*Β	√	√	√		√	
	Α*Γ	√	√	√			√
	Α*Δ						
	Α*Ε	√	√	√	√	√	
	Β*Γ						
	Β*Δ						
	Β*Ε	√	√	√	√	√	
	Γ*Δ						
	Γ*Ε	√	√	√		√	√
	Δ*Ε						

- Ο ρυθμός λαθών (failure rate) έχουν τον ισχυρότερο αντίκτυπο σε όλους σχεδόν τους δείκτες απόδοσης (εκτός από τις χρηματικές απώλειες), υπό την έννοια ότι λάθη τα οποία οδηγούν σε διόρθωση υποβαθμίζουν σημαντικά την απόδοση του συστήματος παροχής υπηρεσιών.
- Ο αντίκτυπος του ρυθμού λαθών (failure rate) είναι πιο έντονος όταν συνδυάζεται με την εξολοκλήρου επαναληπτική επεξεργασία (single rework), με την έννοια ότι όσο μεγαλύτερος είναι ο αριθμός των λαθών και όσο περισσότερος χρόνος χρειάζεται για τη διόρθωσή τους, τόσο επιδεινώνεται η απόδοση του συστήματος.
- Οι χρηματικές απώλειες επηρεάζονται κυρίως από το ύψος των λαθών και την ικανότητα διόρθωσης λαθών (inability to rework rate), δηλ. όσο μεγαλύτερη είναι η πιθανότητα να μη διορθωθεί ένα σφάλμα, σε συνδυασμό με αυξημένα λάθη, τόσο μεγαλύτερες θα είναι οι σχετικές χρηματικές απώλειες.
- Η αδυναμία εντοπισμού του λάθους (failure to detect rate) επηρεάζει το σύνολο των δεικτών απόδοσης του συστήματος (ιδιαίτερα την ικανοποίηση του πελάτη και τις

χρηματικές απώλειες), αν και σε μικρότερο βαθμό. Δηλαδή, όσο πιο γρήγορα εντοπιστεί το λάθος, τόσο το καλύτερο για όλες τις πτυχές της απόδοσης.

- Ο συνολικός χρόνος, ο χρόνος αναμονής, οι εργασίες σε εξέλιξη, η χρήση του προσωπικού και η ικανοποίηση του πελάτη δεν επηρεάζονται όταν εφαρμόζεται η πρακτική διόρθωσης πολλαπλών σταδίων (multiple rework stage), με την έννοια ότι όταν το σφάλμα εντοπίζεται και διορθώνεται στην πηγή ωφελείται το συνολικό σύστημα εξυπηρέτησης.

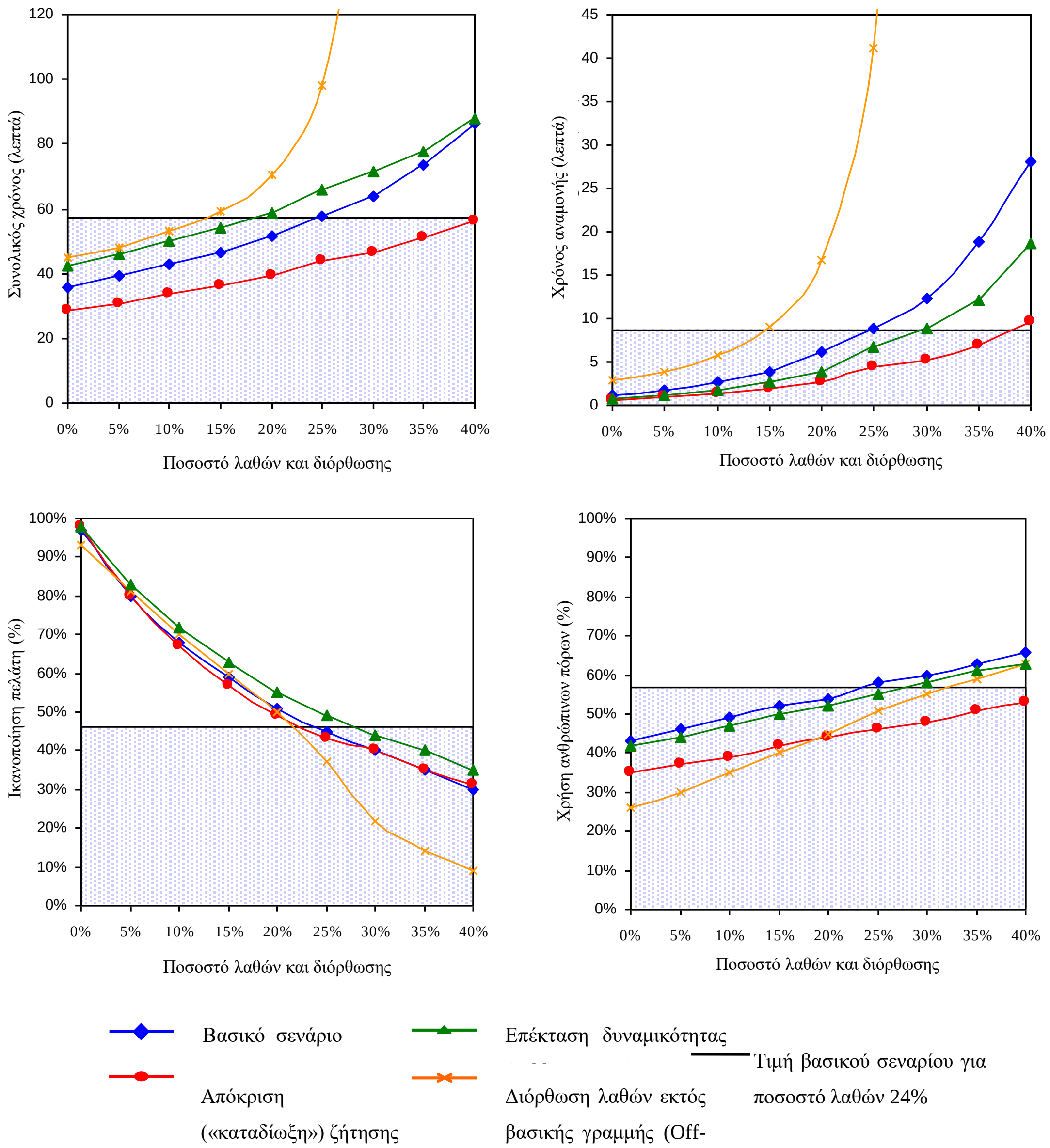
Από τα παραπάνω συμπεραίνουμε ότι η λήψη μέτρων για την αποτροπή των λαθών έχει κομβική σημασία για τη βελτίωση της απόδοσης ενός τυπικού συστήματος παροχής υπηρεσιών. Εξίσου σημαντικές είναι η έγκαιρη ανίχνευση και η ευαισθητοποίηση για τις αιτίες των λαθών. Τέλος, ο αντίκτυπος ενός λάθους στην απόδοση του συστήματος μειώνεται, αν το λάθος μπορεί να εντοπιστεί και να διορθωθεί στο στάδιο στο οποίο συνέβη.

<u>Β. Διοικητικές πρακτικές αντιμετώπισης προβλημάτων ποιότητας στις υπηρεσίες</u>

Προκειμένου να ελεγχθεί η αποτελεσματικότητα των τριών διοικητικών πρακτικών που αναφέραμε παραπάνω, επαναλάβαμε τα πειράματα σε μια ευρωπαϊκή εταιρεία χρηματοοικονομικών υπηρεσιών. Συγκεκριμένα, στα πλαίσια ενός τριμηνιαίου έργου βελτίωσης, συλλέξαμε δεδομένα (όπως χρόνους αφίξεων και επεξεργασίας, ποσοστά λάθους και διόρθωσης λαθών, τα βασικά αίτια κάθε λάθους, κλπ.) και αξιολογήσαμε την απόδοση των τριών πρακτικών διαχείρισης σε διάφορα επίπεδα των ποσοστών λάθους και διόρθωσης λαθών. Αυτή η ανάλυση δείχνει ότι, υπό ορισμένες συνθήκες, μια διοικητική πρακτική μπορεί να παράσχει αποτελέσματα αντίθετα από τις αρχικές προθέσεις, εάν η πολιτική προκαλεί αύξηση των επιπέδων λάθους και διόρθωσης πέραν ενός ορισμένου επιπέδου (Σχήμα Ε.5).

Στην περίπτωση της πρακτικής «απόκριση (καταδίωξη) ζήτησης» (chase demand), για παράδειγμα, το σύστημα φαίνεται να επωφελείται σε σχέση με όλους τους δείκτες απόδοσης. Ωστόσο, αν υιοθετώντας τη πρακτική αυτή, τα ποσοστά λαθών αυξηθούν πέραν του 40%, τα οφέλη φαίνεται να εξαφανίζονται. Σημειώνουμε ότι η (μη σκόπιμη) αύξηση του ποσοστού λαθών μπορεί να συμβεί λόγω της πίεσης για αύξηση παραγωγικότητας, η οποία μπορεί να υποβαθμίσει την ποιότητα της εργασίας και, τελικά, την συνολική απόδοση του συστήματος (Oliva και Sterman, 2001).

Η πρακτική «επέκταση δυναμικότητας» (add capacity), βελτιώνει το χρόνο αναμονής, την ικανοποίηση του πελάτη, καθώς και το συνολικό χρόνο. Ωστόσο, η χαμηλή εμπειρία ή παραγωγικότητα του νέου προσωπικού θα μπορούσε να αντισταθμίσει τα οφέλη από την επέκταση δυναμικότητας, τουλάχιστον βραχυπρόθεσμα. Έτσι, αν τα λάθη αυξηθούν, υιοθετώντας αυτή την πρακτική πέραν του 17%, τα οφέλη φαίνεται να εξαφανίζονται. Τέλος, η πρακτική «διόρθωση λαθών εκτός βασικής γραμμής» (off-line processing of failures), παρουσιάζει κατώτερα αποτελέσματα σε όλες τις πτυχές της απόδοσης, λόγω α) των χαμηλότερων επιπέδων παραγωγικότητας του προσωπικού και β) του γεγονότος ότι το επιπλέον προσωπικό έχει αφιερωθεί αποκλειστικά στην αντιμετώπιση προβλημάτων ποιότητας.



Σχήμα Ε.5: Σύγκριση διοικητικών πρακτικών για την αντιμετώπιση προβλημάτων ποιότητας

5. Κυψελοειδής δομή εργασιών και καταλληλότητα της στις υπηρεσίες

Συνοπτική ανασκόπηση σχετικής βιβλιογραφίας

Η κυψελοειδής δομή εργασιών αποσυνθέτει ένα λειτουργικά οργανωμένο σύστημα παραγωγής σε ημιαυτόνομες υπο-μονάδες που είναι αφιερωμένες στην παραγωγή ειδών με παρόμοια χαρακτηριστικά σχεδιασμού και επεξεργασίας (Hyer και Brown, 1999). Παλαιότερες έρευνες στην κυψελοειδή παραγωγή στον τομέα της μεταποίησης ανέφεραν σημαντικά οφέλη (π.χ. μείωση του αποθέματος εν εξελίξει, χρόνου προετοιμασίας, μετακίνησης υλικών), υπό τρεις προϋποθέσεις: α) τα οφέλη από την υιοθέτηση της κυψελοειδούς δομής (κυρίως η μείωση του χρόνου προετοιμασίας για την παραγωγή διαφορετικών ειδών) πρέπει να ξεπερνούν τα οφέλη από τη συγκέντρωση πόρων (χαρακτηριστικό της λειτουργικής δομής), β) η ζήτηση είναι σταθερή, δεδομένου ότι οι κυψελοειδείς δομές (που επικεντρώνονται στην παραγωγή συγκεκριμένων προϊόντων) λειτουργούν καλύτερα σε περιβάλλοντα όπου η ζήτηση είναι σταθερή, και γ) η επιχείρηση έχει την ικανότητας να διαχειριστεί σωστά τις προκλήσεις μετάβασης από τη λειτουργική στην κυψελοειδή δομή (όπως τεχνικές, οικονομικές και προκλήσεις που σχετίζονται με τον ανθρώπινο παράγοντα).

Όσον αφορά τις υπηρεσίες, οι κυψελοειδείς λειτουργίες έχουν μελετηθεί κυρίως στον τομέα της υγείας και στις χρηματοοικονομικές υπηρεσίες, όπου οι διάφορες επιχειρησιακές μονάδες επικεντρώνονται σε χαμηλό αριθμό λειτουργιών για να μειώσουν την πολυπλοκότητα και να αυξήσουν την αποτελεσματικότητα μέσω εστίασης στην επεξεργασία παρόμοιων υπηρεσιών. Αν και τα οφέλη που έχουν αναφερθεί από την υιοθέτηση κυψελοειδών δομών σε ορισμένα περιβάλλοντα υπηρεσιών είναι σημαντικά, η σχετική έρευνα στις υπηρεσίες είναι μάλλον περιορισμένη σε σχέση με τη μεταποίηση.

Βάσει προηγούμενων ερευνητικών προσπαθειών, οι πάροχοι υπηρεσιών έχουν να αντιμετωπίσουν δύο κατηγορίες προκλήσεων κατά τη μετάβαση σε κυψελοειδή δομές εργασίας: α) κοινές προκλήσεις με τη μεταποίηση και β) προκλήσεις προερχόμενες από τα μοναδικά χαρακτηριστικά των υπηρεσιών. Η πρώτη κατηγορία περιλαμβάνει την απώλεια συνεργειών από τη συγκέντρωση ανθρώπινων πόρων και την ικανότητα ανταπόκρισης στις αλλαγές της ζήτησης, ενώ η δεύτερη κατηγορία περιλαμβάνει την πιθανή δυσαρέσκεια των πελατών από την αύξηση της αρχικής ουράς αναμονής. Ως εκ τούτου, η μετάβαση από λειτουργικές σε κυψελοειδείς δομές στα συστήματα υπηρεσιών δεν μπορεί να βασιστεί αποκλειστικά στη σχετική έρευνα που έχει επικεντρωθεί στη μεταποίηση.

Συνοπτική παρουσίαση μοντέλου προσομοίωσης και πειραμάτων

Για να ερευνήσουμε την καταλληλότητα της κυψελοειδούς έναντι της λειτουργικής δομής στις υπηρεσίες, χρησιμοποιήσαμε πειραματικό σχεδιασμό με προσομοίωση σε ένα τυπικό σύστημα υπηρεσιών στο χρηματοπιστωτικό τομέα. Το υπό μελέτη σύστημα αφορά α) επιχειρησιακή μονάδα υποστήριξης (back-office) που επεξεργάζεται εταιρικές πράξεις - δηλαδή γεγονότα που ξεκινούν από εταιρείες που διαπραγματεύονται στο χρηματιστήριο και ενδέχεται να επηρεάσουν τις αξίες (π.χ. μετοχών) που εκδίδονται από αυτές τις εταιρείες - καθώς και β) τηλεφωνικό κέντρο εξυπηρέτησης πελατών το οποίο απαντά σε ερωτήματα σχετικά με αυτές τις εταιρικές πράξεις.

Το σύστημα εξυπηρετεί πελάτες σε διαφορετικές αγορές, οι οποίες είναι οργανωμένες σε τρεις κατηγορίες (Α, Β και Γ) βάσει κοινών χαρακτηριστικών (π.χ. ώρες και κανόνες λειτουργίας). Επίσης, επεξεργάζεται δύο τύπους εταιρικών πράξεων, τις *υποχρεωτικές* και τις *επιλεκτικές*. Οι πρώτες αφορούν μεταβολές στα χαρακτηριστικά χρεογράφων οι οποίες επιβάλλονται στους κατόχους τίτλων από την εκδότρια εταιρεία (π.χ. αλλαγές ονόματος). Οι δεύτερες, παρέχουν τη δυνατότητα στους κατόχους τίτλων να επιλέγουν μεταξύ διαφόρων επιλογών που σχετίζονται με την εταιρική ενέργεια (π.χ. προαιρετικό μέρισμα). Ο κύκλος ζωής μια εταιρικής πράξης περιλαμβάνει τις παρακάτω εργασίες:

- *Συλλογή πληροφοριών*, δηλ. συλλογή και επικύρωση πληροφοριών σχετικά με εταιρικές πράξεις από παρόχους οικονομικών δεδομένων (π.χ. Bloomberg) και ανακοίνωση αυτών των συμβάντων στα πληροφοριακά συστήματα και στην ιστοσελίδα της εταιρείας
- *Λήψη οδηγιών*, δηλ. παρακολούθηση πελατών και εκτέλεση των οδηγιών τους (ισχύει μόνο για τις υποχρεωτικές πράξεις)
- *Εκτέλεση πληρωμών*, δηλ. τον υπολογισμό των τελικών δικαιωμάτων και την εκτέλεση των πληρωμών.

Το υπάρχον σύστημα είναι οργανωμένο σύμφωνα με τη λειτουργική δομή (δηλ. εξειδικευμένες ομάδες χειρίζονται κάθε μία από τις παραπάνω εργασίες) ενώ χαρακτηρίζεται από υψηλή μεταβλητότητα της ζήτησης. Για να αναπτύξουμε το μοντέλο προσομοίωσης χρησιμοποιήσαμε την ακόλουθη προσέγγιση. Πρώτον, ως εισροές του μοντέλου επιλέξαμε εκείνους τους παράγοντες οι οποίοι έχουν αναγνωριστεί ως σημαντικοί από τη σχετική βιβλιογραφία. Οι παράγοντες και τα επίπεδα τους παρουσιάζονται στον Πίνακα Ε.5.

Πίνακας Ε.5: Παράγοντες και επίπεδα του πλήρους-παραγοντικού (full factorial) πειράματος

Παράγοντες (Factors)	**Περιγραφή (Description)**	**Επίπεδα (Level)**	
Α. Εξάρτηση απόδοσης εργαζομένων (από την κατάσταση του συστήματος) (State Dependency)	Αφορά το βαθμό κατά τον οποίο η απόδοση των εργαζομένων εξαρτάται από την κατάσταση του συστήματος. Περιλαμβάνει δύο επίπεδα: *«εξαρτημένη»* σημαίνει ότι οι εργαζόμενοι προσαρμόζουν τη ταχύτητα και την ποιότητα της εργασίας τους καθώς η κατάσταση του συστήματος (φόρτος εργασίας και κόπωση) μεταβάλλεται, ενώ η *«ανεξάρτητη»* υποθέτει ότι ο χρόνος επεξεργασίας και η ποιότητα παραμένουν αμετάβλητοι	Ανεξάρτητη-Α (State Independent)	Εξαρτημένη-Ε (State Dependent)
Β. Ευελιξία εργαζομένων (Flexibility)	Αφορά την ευελιξία των εργαζομένων να χειριστούν διαφορετικές εργασίες. Έχει δύο επίπεδα: στο πρώτο επίπεδο, οι εργαζόμενοι είναι ειδικευμένοι, δηλαδή εκτελούν περιορισμένες εργασίες που απαιτούν ιδιαίτερες δεξιότητες, μειώνοντας έτσι την ανάγκη προετοιμασίας. Στο δεύτερο επίπεδο, οι εργαζόμενοι έχουν πολλαπλή κατάρτιση, δηλαδή εκτελούν όλες τις εργασίες, αλλά θα πρέπει επίσης να εκτελέσουν την απαραίτητη προετοιμασία όταν αλλάζουν εργασίες (ή αγορές)	Εξειδικευμένη κατάρτιση-ΕΚ (Single-Skilled)	Πολλαπλή κατάρτιση-ΠΚ (Multi-Skilled)
Γ. Μείωση χρόνου προετοιμασίας (Setup Reduction)	Αφορά την πιθανή μείωση στο χρόνο προετοιμασίας που μπορεί να πραγματοποιηθεί με κανόνες προτεραιοποίησης οι οποίοι ομαδοποιούν παρόμοιες εργασίες και τις αναθέτουν σε συγκεκριμένους εργαζομένους (για την αποφυγή πολλαπλής προετοιμασίας λόγω εναλλαγών). Τα επίπεδα είναι 0.0, 0.30 και 0.60. Για παράδειγμα, για αρχικό χρόνο προετοιμασίας 2 min, τιμή ίση με 0.60 σημαίνει ότι ο χρόνος εγκατάστασης θα είναι κατά 60% μειωμένος από την αρχική τιμή (δηλ. 0.8 min).	0.0, 0.3, 0.6	
Δ. Μείωση αλληλεπιδράσεων μεταξύ εργαζομένων (Interaction Intensity Reduction)	Αφορά την πιθανή μείωση της συχνότητας αλληλεπιδράσεων μεταξύ των εργαζομένων όταν η δομή μετατρέπεται από λειτουργική σε κυψελοειδή. Τα επίπεδα είναι: 0.0, 0.30 και 0.60, όπου κάθε τιμή υποδεικνύει το ποσοστό μείωσης στην πιθανότητα να επαναληφθεί μια εργασία λόγω λάθους από το προηγούμενο στάδιο. Για παράδειγμα, αν η πιθανότητα επανάληψης μιας εργασίας είναι 20% και ο παράγοντας μείωσης λαμβάνει τιμή ίση με 0.60, τότε η πιθανότητα επανεπεξεργασίας θα μειωθεί στο 8%	0.0, 0.3, 0.6	
Ε. Αναλογία χρόνου προετοιμασίας (Setup Ratio)	Αφορά τη σχέση μεταξύ του χρόνου προετοιμασίας στη λειτουργική (εναλλαγή μεταξύ ομοειδών εργασιών σε διαφορετικές αγορές) και του αντίστοιχου στην κυψελοειδή δομή (εναλλαγή μεταξύ διαφορετικών εργασιών στις ίδιες αγορές), δεδομένου ότι και στα δύο συστήματα υπάρχει χρόνος προετοιμασίας. Τα επίπεδα είναι: 0.5, 1 και 2, το οποίο καταδεικνύει ότι ο χρόνος προετοιμασίας της κυψελοειδής δομής, μπορεί να είναι ο μισός, ίσος ή διπλάσιος από το χρόνο προετοιμασίας στη λειτουργική δομή.	0.5, 1.0, 2.0	

Οι δείκτες που χρησιμοποιήσαμε για να αξιολογήσουμε τις επιδράσεις των παραπάνω παραγόντων περιλαμβάνουν την ποσοστιαία διαφορά του εκάστοτε δείκτη απόδοσης μεταξύ της λειτουργικής και της κυψελοειδούς δομής. Ενδεικτικά για το δείκτη συνολικό χρόνο (ΣΧ), η ποσοστιαία διαφορά του συνολικού χρόνου (Ποσοστιαία Διαφορά Συνολικού Χρόνου ή ΠΔΣΧ) είναι:

$$\boldsymbol{ΠΔΣΧ = -100 \times \frac{ΣΧ_{ΚΥΨΕΛΟΕΙΔΗ} - ΣΧ_{ΛΕΙΤΟΥΡΓΙΚΗ}}{ΣΧ_{ΛΕΙΤΟΥΡΓΙΚΗ}}} \quad \textbf{(Ε.1)}$$

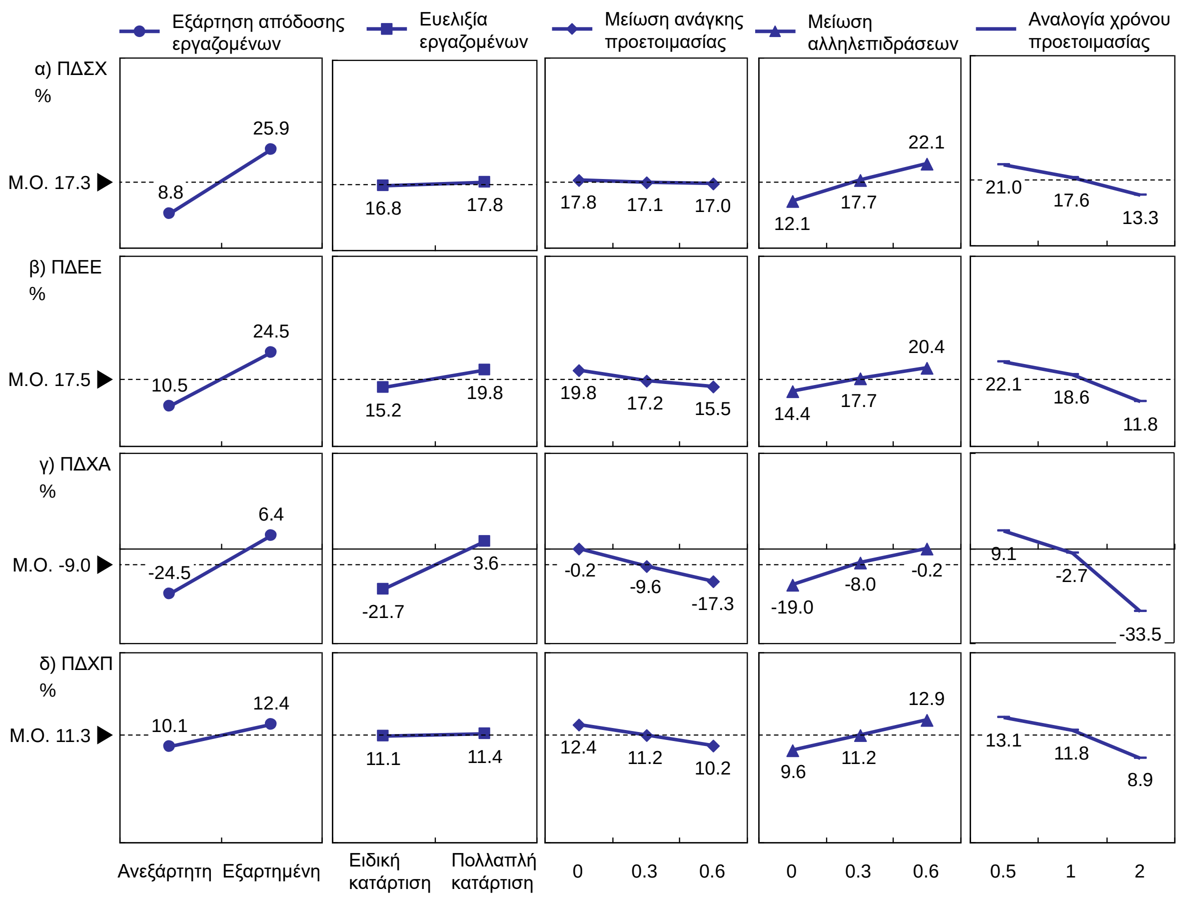
Μια τιμή ΠΔΣΧ μεγαλύτερη από το μηδέν υποδηλώνει ότι η μετάβαση από τη λειτουργική στην κυψελοειδή δομή έχει ως αποτέλεσμα τη βελτίωση του συνολικού χρόνου. Οι άλλοι τρεις δείκτες είναι οι εξής: εργασίες σε εξέλιξη (ΠΔΕΕ), χρόνος αναμονής (ΠΔΧΑ), και χρήση ανθρώπινων πόρων (ΠΔΧΠ).

Δεύτερον, για να μοντελοποιήσουμε τη λειτουργική (βασική) δομή του συστήματος (το οποίο είναι πραγματικό και λειτουργεί σε υφιστάμενη εταιρία παροχής χρηματοοικονομικών υπηρεσιών) χρησιμοποιήσαμε υπάρχουσες διαδικασίες, ιστορικά δεδομένα, άμεσες παρατηρήσεις, ενώ τα στοιχεία που δεν υπήρχαν ολοκληρώθηκαν βάσει παραδοχών με το προσωπικό και τα στελέχη διοίκησης της εταιρίας. Ειδικά, για να αναπτύξουμε τις σχέσεις μεταξύ του χρόνου και της ποιότητας επεξεργασίας ως συναρτήσεις του φόρτου εργασίας και της κόπωσης (απαραίτητο για την ποσοτικοποίηση του παράγοντα «Α. Εξάρτηση από την κατάσταση του συστήματος»), χρησιμοποιήσαμε την εργασία των Kc και Terwiesch (2009) στον τομέα της υγείας. Για τον προσδιορισμό των παραμέτρων αυτών πραγματοποιήσαμε συνεντεύξεις με 26 από τους 40 εργαζομένους του υπό μελέτη συστήματος (η διαδικασία που ακολουθήθηκε περιγράφεται αναλυτικά στο κύριο μέρος της διατριβής).

Τρίτον, όσον αφορά τα πειράματα προσομοίωσης, για κάθε συνδυασμό των τιμών των παραγόντων, εκτελέσαμε δύο προσομοιώσεις, μία για κάθε δομή. Δεδομένου ότι ο παράγοντας «Δ. Μείωση αλληλεπιδράσεων μεταξύ εργαζομένων» εφαρμόζεται μόνο στην κυψελοειδή δομή, οι αριθμοί των προσομοιώσεων που εκτελέσαμε για την κυψελοειδή και τη λειτουργική δομή είναι 2^2x3^3x50 = 5400 και 2^2x3^2x50 = 1800, αντίστοιχα (όπου 50 είναι ο αριθμός επαναλήψεων για κάθε σετ πειραμάτων). Τέλος, σημειώνεται ότι η περίοδος προσομοίωσης ήταν 62 εργάσιμες ημέρες (τρεις μήνες), εκ των οποίων οι πρώτες 20 ημέρες αφιερώθηκαν στην προθέρμανση του συστήματος και τα σχετικά αποτελέσματα δεν χρησιμοποιήθηκαν στην ανάλυση. Τα λογισμικά Arena (11.0) και Minitab (15) χρησιμοποιήθηκαν για την ανάπτυξη του μοντέλου προσομοίωσης και στατιστική επεξεργασία των αποτελεσμάτων αντίστοιχα.

Αποτελέσματα προσομοίωσης

Τα γραφήματα στο Σχήμα Ε.6 υποδεικνύουν την επίδραση των κύριων παραγόντων στους δείκτες απόδοσης. Σημειώνεται ότι τα στοιχεία του Πίνακα Ε.6 βασίζονται στην ανάλυση διακύμανσης (ANOVA) των σημαντικότερων παραγόντων του Πίνακα Ε.5 (Παράρτημα D). Σύμφωνα με την προηγούμενη βιβλιογραφία, τα αποτελέσματα υποδηλώνουν ότι η μετάβαση στην κυψελοειδή δομή βελτιώνει (μειώνει) το συνολικό χρόνο και τις εργασίες σε εξέλιξη (κατά 17% κατά μέσο όρο) καθώς και τη χρήση ανθρώπινων πόρων (κατά 11%). Τα αποτελέσματα επιβεβαιώνουν επίσης μια πιθανή αρνητική επίδραση της κυψελοειδούς δομής στις υπηρεσίες, δηλαδή την αύξηση της αρχικής περιόδου αναμονής. Πράγματι, όπως υποδεικνύεται στο Σχήμα Ε.6γ, ο χρόνος αναμονής επιδεινώνεται (αυξάνεται) κατά μέσο όρο κατά 9% λόγω της μετάβασης στην κυψελοειδή δομή. Σημειώνεται ότι οι μέσοι όροι καθορίζονται λαμβάνοντας υπόψη όλα τα επίπεδα των πέντε παραγόντων.



Σχήμα Ε.6: Κύριες επιδράσεις (μέσοι όροι) για (α) συνολικό χρόνο (ΠΔΣΧ), (β) εργασίες σε εξέλιξη (ΠΔΕΕ), (γ) χρόνο αναμονής (ΠΔΧΑ), και (δ) χρήσης ανθρώπινων πόρων (ΠΔΧΠ)

Η βελτίωση της απόδοσης της κυψελοειδούς δομής αποδίδεται σε διάφορους παράγοντες: α) μειωμένη ανάγκη για προετοιμασία εναλλαγής από τη μία εργασία στην άλλη, β) λιγότερα βήματα για τη διόρθωση λαθών (καθότι οι εργαζόμενοι μπορούν να διορθώσουν τα δικά τους λάθη), γ) ένα λιγότερο βήμα έγκρισης όσον αφορά τα ερωτήματα των πελατών (λόγω της εξάλειψης του ρόλου του επικεφαλής της ερευνητικής ομάδας), και τέλος δ) το γεγονός ότι ο φόρτος εργασίας είναι καλύτερα κατανεμημένος στην κυψελοειδή δομή. Συγκεκριμένα:

- Ο παράγοντας «Α. Εξάρτηση απόδοσης εργαζομένων (από την κατάσταση του συστήματος)» έχει την ισχυρότερη επίδραση στο συνολικό χρόνο και στις εργασίες σε εξέλιξη (Σχήματα Ε.6 α και β). Παρατηρούμε επίσης ότι η διαφορά μεταξύ των δύο δομών καθίσταται σημαντικά υψηλότερη στο σενάριο της εξαρτημένης απόδοσης, υπό την έννοια ότι η επιτάχυνση του ρυθμού εργασίας και η επακόλουθη κόπωση επιβραδύνει τελικά το χρόνο επεξεργασίας και αυξάνει τα λάθη. Αυτή η δυσλειτουργική συμπεριφορά δεν είναι εμφανής στο σενάριο της ανεξάρτητης απόδοσης, όπου ο χρόνος και η ποιότητα επεξεργασίας θεωρούνται ανεξάρτητα από το φόρτο εργασίας και την κόπωση.

- Ο παράγοντας «Β. Ευελιξία εργαζομένων» έχει ισχυρό αντίκτυπο στο χρόνο αναμονής (Σχήμα Ε.6 γ). Ωστόσο, η επίδραση του στα υπόλοιπα μέτρα απόδοσης δεν είναι τόσο υψηλή όσο παρατηρήθηκε σε αντίστοιχες μελέτες στη μεταποίηση. Επιπλέον, η πολλαπλή κατάρτιση, μειώνει τον αρχικό χρόνο αναμονής στην κυψελοειδή δομή, ενώ η εξειδικευμένη κατάρτιση παράγει καλύτερα αποτελέσματα στη λειτουργική δομή. Αυτό σημαίνει ότι μπορούν να επιτευχθούν περισσότερα οφέλη εάν εφαρμοστεί το κατάλληλο επίπεδο κατάρτισης σε κάθε δομή.
- Ο παράγοντας «Γ. Μείωση χρόνου προετοιμασίας» έχει ισχυρή επίδραση στο χρόνο αναμονής και στη χρήση των ανθρώπινων πόρων (Σχήμα Ε.6 γ και δ). Επιπλέον, η βελτίωση της απόδοσης της κυψελοειδούς δομής μειώνεται καθώς αυξάνεται το επίπεδο του παράγοντα, υποδηλώνοντας ότι η λειτουργική δομή μπορεί να επωφεληθεί περισσότερο από μια σημαντική μείωση του χρόνου προετοιμασίας μέσω κανόνων προτεραιοποίησης.
- Ο παράγοντας «Δ. Μείωση αλληλεπιδράσεων μεταξύ εργαζομένων» έχει ισχυρή επίδραση σε όλους τους δείκτες απόδοσης. Προφανώς, όσο μεγαλύτερη είναι η μείωση των αλληλεπιδράσεων μεταξύ των εργαζομένων, τόσο υψηλότερη είναι η βελτίωση της απόδοσης. Ως εκ τούτου, η μείωση των αλληλεπιδράσεων μεταξύ των εργαζομένων μπορεί επίσης να αποτελέσει ένα σημαντικό μοχλό βελτίωσης στις υπηρεσίες, εκτός από τη μείωση του χρόνου προετοιμασίας.
- Ο παράγοντας «Ε. Αναλογία χρόνου προετοιμασίας» έχει την ισχυρότερη επίδραση στο χρόνο αναμονής και στη χρήση των ανθρώπινων πόρων (Σχήμα Ε.6 γ και δ), ενώ η απόδοση της κυψελοειδούς δομής μειώνεται όσο αυξάνεται το επίπεδο του παράγοντα.

6. Συμπεράσματα

Συνοψίζουμε τα κυριότερα συμπεράσματα της παρούσας διατριβής ταξινομημένα στις παρακάτω τέσσερις ενότητες.

Στον τομέα των λιτών υπηρεσιών (1η ευκαιρία για περαιτέρω έρευνα), χρησιμοποιώντας το έργο των Hopp και Spearman (2004), de Treville και Antonakis (2006) και Hopp (2013) καταλήξαμε σε έναν νέο ορισμό για την ΛΠ. Συγκεκριμένα, ορίζουμε ως «στόχο της ΛΠ τη μακροπρόθεσμη κερδοφορία σύμφωνα με τη στρατηγική της εταιρείας. Αυτή επιτυγχάνεται με την ελαχιστοποίηση: των περιττών λειτουργιών (waste), της ανεπιθύμητης *ετερογένειας* ή *μεταβλητότητας* (undesirable variability), και των διαθέσιμων πόρων (buffering costs) (ή τη διατήρηση τους στο επίπεδο που μεγιστοποιούν τα κέρδη και τις ταμειακές ροές) και ένα αυτό-παρακινούμενο (self-motivated) εργατικό δυναμικό για την προώθηση της συνεχούς βελτίωσης». Ο ορισμός αυτός περιλαμβάνει ορισμένα σημαντικά χαρακτηριστικά.

Πρώτον, διατηρεί τις βασικές έννοιες της ελαχιστοποίησης των περιττών λειτουργιών και της επίτευξης μακροπρόθεσμης κερδοφορίας με τους ελάχιστους πόρους (αποθέματα, χρόνο και ανθρώπινο δυναμικό ή/και ποιότητα για συγκεκριμένα είδη υπηρεσιών). Ωστόσο, η ελαχιστοποίηση των περιττών λειτουργιών και το κόστος των πόρων εξαρτώνται από τα ιδιαίτερα χαρακτηριστικά κάθε υπηρεσίας. Για παράδειγμα, εκτός από τους ανθρώπινους πόρους ενός οργανισμού, η δυναμικότητα μπορεί να περιλαμβάνει εξωτερικούς προμηθευτές (δεδομένου ότι τμήματα ή ολόκληρες υπηρεσίες θα μπορούσαν να ανατεθούν σε εξωτερικούς προμηθευτές), πελάτες (δεδομένου ότι οι πελάτες εκτελούν τμήματα ή εξ ολοκλήρου την υπηρεσία μέσω αυτοεξυπηρέτησης) και τεχνολογία (αφού, για παράδειγμα, η Τεχνητή Νοημοσύνη αντικαθιστά σταδιακά την ανθρώπινη εργασία σε ορισμένους τομείς). Η ποιότητα μπορεί επίσης να χρησιμοποιηθεί ως διαθέσιμος πόρος, αφού σε ορισμένα περιβάλλοντα υπηρεσιών μπορεί να προσαρμοστεί ώστε το προσωπικό να αντιμετωπίσει τις διακυμάνσεις της ζήτησης. Ως εκ τούτου, η κατανόηση των παραγόντων ελαχιστοποίησης των περιττών λειτουργιών και η εξεύρεση του κατάλληλου συνδυασμού των διαθέσιμων πόρων είναι κρίσιμα συστατικά για την επίτευξη λιτών υπηρεσιών.

Δεύτερον, εισάγει την έννοια της ανεπιθύμητης *ετερογένειας* ή *μεταβλητότητας* (undesirable variability), υπό την έννοια ότι δεν είναι όλοι οι τύποι μεταβλητότητας ανεπιθύμητοι, αλλά μόνο εκείνοι που δεν υποστηρίζουν τη στρατηγική του οργανισμού. Για παράδειγμα, η προσφορά μιας ευρείας γκάμας προϊόντων και υπηρεσιών προσαρμοσμένες στις ιδιαίτερες ανάγκες των πελατών (high customization) καθώς και η προώθηση εκτενούς συμμετοχής των πελατών στην παραγωγή των υπηρεσιών (high customer participation) είναι λογικό να είναι επιθυμητές από εταιρείες παροχής υπηρεσιών που ακολουθούν στρατηγική διαφοροποίησης. Ως εκ τούτου, ο προσδιορισμός του τι συνιστά ανεπιθύμητη μεταβλητότητα και η εύρεση πρακτικών για την εξάλειψή της (π.χ. μέσω πρακτικών αρθρωτής δομής, modularization- και ευελιξίας των πόρων), είναι επίσης κρίσιμοι παράγοντες για την επίτευξη λιτών υπηρεσιών.

Τρίτον, περιλαμβάνει το συστατικό του αυτό-παρακινούμενου εργατικού δυναμικού, το οποίο αποτελεί την κινητήρια δύναμη για την επίτευξη συνεχούς βελτίωσης. Όπως αναφέραμε, η λιτή παραγωγή σε πολλές περιπτώσεις χρησιμοποιήθηκε ως μια καθαρή προσπάθεια μείωσης του κόστους (μέσω απολύσεων). Ωστόσο, η προσέγγιση αυτή μπορεί να θέσει σε κίνδυνο τη μακροβιότητα ενός οργανισμού, υπό την έννοια ότι οι απολύσεις μπορεί να επηρεάσουν την ψυχολογία του προσωπικού και συνεπώς τη δέσμευσή τους για συνεχόμενη βελτίωση του οργανισμού. Από την άλλη, η διατήρηση πλεονάζοντος προσωπικού (ως αποτέλεσμα της λιτής παραγωγής) μπορεί να επιδεινώνει τις οικονομικές επιδόσεις ενός οργανισμού. Οι ειδικοί προτείνουν να ακολουθείται μια ισορροπημένη προσέγγιση κατά την οποία τα ανώτερα διευθυντικά στελέχη πρέπει να α) εξισορροπήσουν τους βραχυπρόθεσμους με τους μακροπρόθεσμους στόχους, β) αναθέτουν το πλεονάζον προσωπικό σε περαιτέρω προσπάθειες βελτίωσης. Στις περιπτώσεις στις οποίες δεν υπάρχει εναλλακτική η διοίκηση πρέπει να επικοινωνεί ξεκάθαρα τα αιτία των απολύσεων.

Παρόλο που ο ορισμός αυτός αφορά τόσο τη μεταποίηση όσο και τις υπηρεσίες, από τα παραπάνω συμπεραίνουμε ότι κάθε στοιχείο πρέπει να προσαρμοστεί ανάλογα με τη στρατηγική του οργανισμού και τα χαρακτηριστικά κάθε υπηρεσίας.

<u>Στον τομέα της επιστήμης των υπηρεσιών</u> (2^{η} ευκαιρία για περαιτέρω έρευνα), αξιοποιήσαμε προηγούμενα ερευνητικά αποτελέσματα σε σχέση με συστήματα ταξινόμησης υπηρεσιών και επιλέξαμε τα σημαντικότερα χαρακτηριστικά που πρέπει να ληφθούν υπόψη για το σχεδιασμό και διαχείριση υπηρεσιών. Προτείναμε ένα νέο εργαλείο, τη Μήτρα Χαρακτηριστικών - Διαδικασιών Υπηρεσιών (ΜΧΔΥ) ή Service Attribute - Process Matrix (SAPM), το οποίο διερευνά την επίδραση των βασικών χαρακτηριστικών ταξινόμησης των υπηρεσιών σε σημαντικές διαδικασίες του κύκλου ζωής τους. Συγκεκριμένα, η ΜΧΔΥ:

- Ενσωματώνει τα σημαντικότερα, βάσει βιβλιογραφίας, χαρακτηριστικά ταξινόμησης των υπηρεσιών σε ένα συστηματικό πλαίσιο. Επιπλέον, διερευνά την επίδραση των χαρακτηριστικών αυτών στις κύριες διαδικασίες του κύκλου ζωής της υπηρεσίας, υποστηρίζοντας με τον τρόπο αυτό την ολοκληρωμένη ανάπτυξη ενός συστήματος υπηρεσιών.

- Εντοπίζει τις αλληλεπιδράσεις μεταξύ των διαφόρων χαρακτηριστικών ταξινόμησης των υπηρεσιών, παρέχοντας πληροφορίες στον σχεδιαστή του συστήματος σχετικά με το πώς μια απόφαση για ένα συγκεκριμένο χαρακτηριστικό θα επηρεάσει τα άλλα σχετικά χαρακτηριστικά.
- Αναδεικνύει τις διαδικασίες με τη μεγαλύτερη πολυπλοκότητα, δηλ. εκείνες τις διαδικασίες που επηρεάζονται από πλήθος παραγόντων, βοηθώντας έτσι τον σχεδιαστή να διαχειριστεί την πολυπλοκότητα της διαδικασίας συμβιβάζοντας αντίρροπα χαρακτηριστικά.

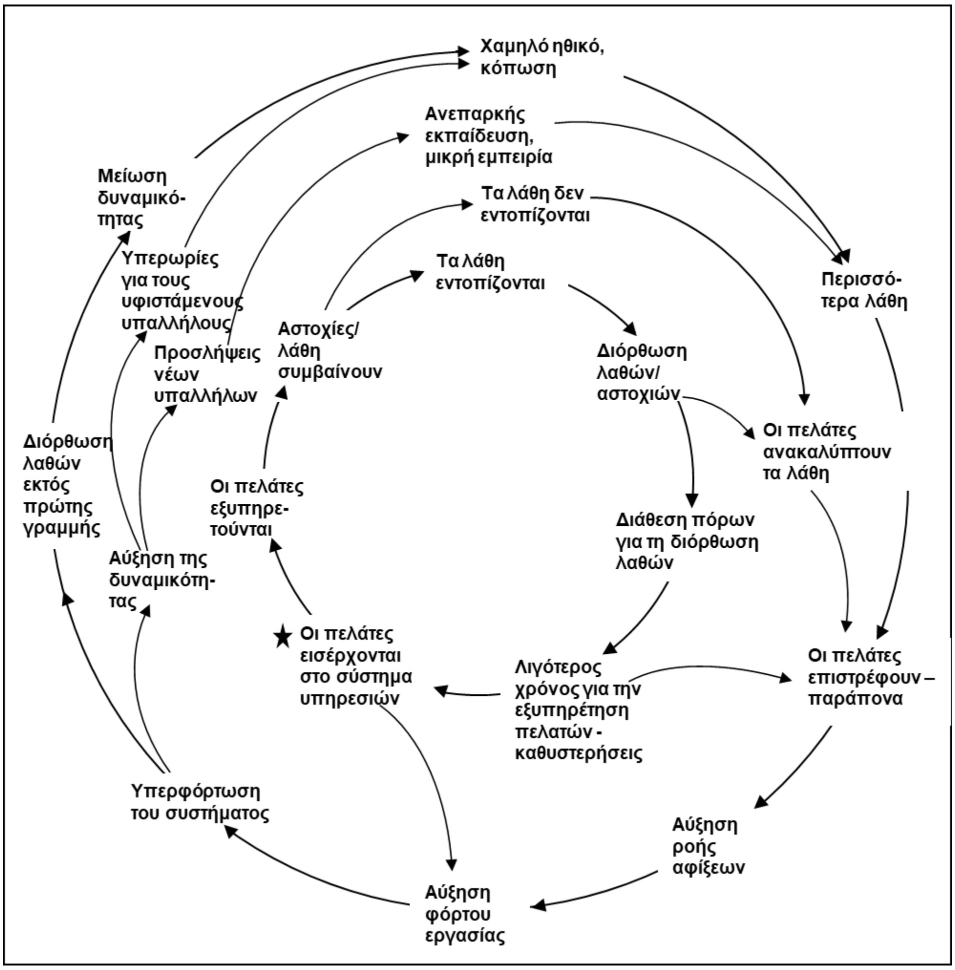
Ένα σημαντικό ερευνητικό συμπέρασμα είναι ότι κανένα σύστημα ταξινόμησης υπηρεσιών δεν είναι καθολικό και εφαρμόσιμο σε όλες τις διαδικασίες του κύκλου ζωής των υπηρεσιών. Από την άποψη των ΛΥ, το συμπέρασμα είναι ότι η ΛΠ δεν μπορεί να εφαρμοστεί με τον ίδιο τρόπο σε κάθε περιβάλλον υπηρεσιών. Θα πρέπει να προσαρμοστεί σε κάθε επιχειρηματική διαδικασία, βάσει των κύριων χαρακτηριστικών που την επηρεάζουν. Συνολικά, τα πιο σημαντικά χαρακτηριστικά σχετίζονται α) με τον *πελάτη*, συμπεριλαμβανομένου του *τύπου* (δηλ. ατόμου ή οργανισμού), του *μοντέλου επαφής* (δηλ. το βαθμό επαφής των πελατών με τον πάροχο των υπηρεσιών) και της *επιρροής του πελάτη* (δηλ. την επιρροή που μπορεί να ασκήσει ο πελάτης στην προσφερόμενη υπηρεσία και στην παροχή της), β) το βαθμό *προσαρμογής του πακέτου υπηρεσιών* στις ιδιαίτερες ανάγκες των πελατών, και γ) το *κανάλι παράδοσης* που χρησιμοποιείται για την παροχή προϊόντων και υπηρεσιών. Οι πιο σύνθετες διαδικασίες που εντοπίστηκαν από την εργασία ταξινόμησης περιλαμβάνουν το *σχεδιασμό και την ανάπτυξη νέων υπηρεσιών*, τη *διαδικασία προμήθειας και πώλησης* και, τέλος. την *παροχή προϊόντων και υπηρεσιών*.

<u>Στον τομέα της ποιότητας των υπηρεσιών</u> ($9^{η}$ ευκαιρία για περαιτέρω έρευνα), συνοψίσαμε τις επιπτώσεις των προβλημάτων ποιότητας στις λειτουργίες των υπηρεσιών στο Σχήμα Ε.7. Το σχήμα είναι εμπνευσμένο από τον κύκλο αστοχιών (cycle of failures) στις υπηρεσίες από τον Schlesinger (1991a), ωστόσο, έχει δημιουργηθεί από την πλευρά των λειτουργιών των υπηρεσιών. Τα προβλήματα στην ποιότητα των υπηρεσιών (π.χ. λάθη), εφόσον εντοπιστούν, οδηγούν σε διορθώσεις (rework), οι οποίες αυξάνουν τη χρήση ανθρώπινων πόρων και το χρόνο ολοκλήρωσης της υπηρεσίας, οδηγώντας τελικά σε καθυστερήσεις στην εξυπηρέτηση των πελατών.

Επιπλέον, τα μη-ανιχνεύσιμα λάθη θα εντοπιστούν σε κάποιο χρονικό σημείο από τους πελάτες, συνήθως αφού έχουν εγκαταλείψει το σύστημα παροχής υπηρεσιών. Κατά συνέπεια, τυχόν προβλήματα ή και καθυστερήσεις στην διεκπεραίωση των αιτημάτων των πελατών κατά την πρώτη επαφή, οδηγούν σε επαναλαμβανόμενες προσπάθειες από τους πελάτες να έρθουν σε επαφή με το σύστημα παροχής υπηρεσιών, πράγμα που αυξάνει τελικά την κανονική ροή αφίξεων. Το γεγονός αυτό, με τη σειρά του, αυξάνει το φόρτο εργασίας δημιουργώντας νέα σημεία συμφόρησης και αυξάνει τις ουρές αναμονής προκαλώντας περαιτέρω καθυστερήσεις.

Όταν το σύστημα υπερφορτωθεί (π.χ. μεγάλες ουρές αναμονής, αυξημένα παράπονα πελατών), η διοίκηση συνήθως αναλαμβάνει δράση. Οι συνήθεις πρακτικές περιλαμβάνουν την επέκταση της δυναμικότητας δηλ. προσθήκη ανθρώπινων πόρων (increasing capacity), την προσπάθεια απόκρισης (ή την «καταδίωξη») της αυξημένης ζήτηση (chasing demand) ή η αντιμετώπιση των προβλημάτων εκτός της γραμμής παραγωγής με την ανάθεση τους σε εργαζόμενους που θα ασχολούνται αποκλειστικά στην επίλυση προβλημάτων (treating failures off-line). Στην πρώτη περίπτωση, αν η δυναμικότητα αυξηθεί σημαντικά, ο χρόνος εξυπηρέτησης θα μειωθεί, με αποτέλεσμα η ικανοποίηση των πελατών να βελτιωθεί και το σύστημα να επιστρέψει σε ικανοποιητική κατάσταση. Ωστόσο, εάν τα προβλήματα ποιότητας αυξάνονται μαζί με την αύξηση της δυναμικότητας (π.χ. λόγω της χρήσης άπειρου προσωπικού), τότε τα οφέλη μπορεί να εξαφανιστούν. Στη δεύτερη περίπτωση, εάν οι εργαζόμενοι πιεστούν για να καλύψουν την αυξημένη ζήτηση, αυξάνοντας την ένταση (περισσότερη προσπάθεια) ή το χρόνο εργασίας (μέσω υπερωριών), μακροπρόθεσμα μπορεί να επέλθει κόπωση η οποία μπορεί να οδηγήσει σε περαιτέρω λάθη.

Η διαχείριση των προβλημάτων εκτός βασικής γραμμής παραγωγής, η οποία χρησιμοποιεί αποκλειστικούς πόρους για την επίλυση των προβλημάτων (π.χ. τμήματα καταγγελιών ή διαχείρισης παραπόνων), μπορεί να μειώσει την δυναμικότητα της βασικής γραμμής (μείωση ανθρώπινων πόρων) και συνεπώς να αυξήσει τον χρόνο απόκρισης και να οδηγήσει σε νέες καθυστερήσεις, πίεση και ενδεχομένως νέα προβλήματα. Επιπλέον, και ίσως το πιο σημαντικό, η εν λόγω πρακτική μεταθέτει την ευθύνη για τα προβλήματα σε άλλα τμήματα, μειώνοντας την ευαισθητοποίηση σχετικά με τις αιτίες και τα αποτελέσματα γέννησης των προβλημάτων (Hopp and Spearman, 2001).



Σχήμα Ε.7: Ο φαύλος κύκλος των προβλημάτων ποιότητας στις λειτουργίες των υπηρεσίες

Τα αποτελέσματα δείχνουν ότι τα προβλήματα ποιότητας υποβαθμίζουν την απόδοση των συστημάτων υπηρεσιών. Μεταφορικά, όσο μεγαλύτερος είναι ο φαύλος κύκλος των αστοχιών, τόσο περισσότερο επιδεινώνεται η απόδοση του συστήματος. Ο κύκλος γίνεται όλο και μεγαλύτερος εάν επιδεινωθούν ορισμένοι ειδικοί παράγοντες του συστήματος. Αυτοί περιλαμβάνουν την ικανότητα του παρόχου υπηρεσιών να λειτουργεί στο κατάλληλο επίπεδο ποιότητας, ταχύτητας ή/και ευελιξίας, την ικανότητα να ανιχνεύει τις αστοχίες εγκαίρως (ποσοστό ανίχνευσης) και να είναι σε θέση να ανακάμψει εγκαίρως και αποτελεσματικά από τις αστοχίες (μέθοδος επανεπεξεργασίας/ διόρθωσης). Επισημαίνεται ότι δεν είναι πάντα προφανές στα στελέχη υπηρεσιών πώς να ξεφύγουν ή να μειώσουν το φαύλο κύκλο προβλημάτων ποιότητας. Για παράδειγμα, τα αποτελέσματά μας δείχνουν ότι οι διάφορες πρακτικές διαχείρισης των προβλημάτων ποιότητας έχουν πλεονεκτήματα και αδυναμίες. Εάν δεν ληφθούν υπόψη οι αδυναμίες, οι πρακτικές αυτές μπορεί να οδηγήσουν μόνο σε βραχυπρόθεσμες βελτιώσεις, ενώ οι κύριες αιτίες των προβλημάτων θα παραμείνουν ανεπίλυτες και ο φαύλος κύκλος θα συνεχιστεί.

Η καλύτερη στρατηγική, κατά την άποψη μας, για τη διαχείριση των προβλημάτων ποιότητας είναι η πρόληψη που οδηγεί στην αποφυγή εξαρχής του φαύλου κύκλου των αστοχιών. Για να γίνει αυτό, όπως ήδη αναφέρθηκε, απαιτούνται οι κατάλληλοι μηχανισμοί όπως διασφάλιση ποιότητας, εγγυήσεις υπηρεσιών, στατιστικοί έλεγχοι ποιότητας και μέθοδοι ανάκτησης υπηρεσιών (Fitzsimmons and Fitzsimmons, 2005). Το σημείο στο οποίο οι μηχανισμοί αυτοί μπορούν να έχουν τη μεγαλύτερη επιτυχία, είναι στο σημείο επαφής με τον πελάτη, όπου και υπάρχει η μεγαλύτερη αβεβαιότητα. Ωστόσο, δεν πρέπει να παραμεληθεί και η σημασία των εν λόγω μηχανισμών σε σχέση με τις εργασίες υποστήριξης, δεδομένου ότι τυχόν λάθη εκεί μπορεί να επηρεάσουν τους πελάτες σε ευρεία κλίμακα.

Επιπλέον, ο σχεδιασμός του συστήματος εξυπηρέτησης θα πρέπει να επανεξετάζεται συνεχώς. Τα προβλήματα ποιότητας και κυρίως αυτά που επαναλαμβάνονται, είναι μια μεγάλη ευκαιρία ανίχνευσης και θεραπείας των αδυναμιών στο σχεδιασμό των υπηρεσιών. Τέτοια προβλήματα είναι συνήθως το αποτέλεσμα της έλλειψης ευελιξίας του συστήματος εξυπηρέτησης να αντιμετωπίσει τις διαφορετικές ανάγκες των πελατών κάτι σύνηθες στις υπηρεσίες. Τέλος, κατά το σχεδιασμό νέων υπηρεσιών ιδιαίτερη βαρύτητα θα πρέπει να δοθεί στην έννοια της λειτουργικότητας (δηλ. ευκολία παροχής των υπηρεσιών). Έχει παρατηρηθεί ότι ορισμένες αδυναμίες σχεδιασμού σε συστήματα υπηρεσιών οφείλονται στην ανεπαρκή συμμετοχή των πελατών ή / και των εργαζομένων στα αρχικά στάδια της διαδικασίας σχεδιασμού. Εν ολίγοις, οι οργανισμοί παροχής υπηρεσιών θα πρέπει να επιδιώκουν την πρόληψη και έγκαιρη ανίχνευση των προβλημάτων, την πλήρη κατανόηση των βαθύτερων αιτίων τους, καθώς και των τρόπων αντιμετώπισής τους μακροπρόθεσμα.

Στον τομέα των κυψελοειδών δομών εργασίας (4^{η} ευκαιρία για περαιτέρω έρευνα), περιγράφουμε στη συνέχεια τα αποτελέσματα της έρευνας καθώς και τα σημεία που χρήζουν προσοχής για τη μετάβαση σε μια κυψελοειδή δομή.

Αντιστάθμιση της απώλειας των ωφελειών από τη συγκέντρωση πόρων. Τα αποτελέσματα της εργασίας μας επιβεβαιώνουν προηγούμενες έρευνες και υποδηλώνουν ότι η μετάβαση σε μια κυψελοειδή δομή βελτιώνει την απόδοση ενός συστήματος υπηρεσιών σε όρους χρόνου ολοκλήρωσης των εργασιών (cycle time), εργασιών σε εξέλιξη (work in progress) και χρήσης ανθρώπινων πόρων (utilization). Αυτό επιτυγχάνεται μέσω της μείωσης της συχνότητας και διάρκειας του χρόνου προετοιμασίας (setup time) για την εναλλαγή από τη μία εργασία σε μία άλλη, την εξάλειψη επαναλαμβανόμενων εργασιών (duplicate activities) και της μείωσης των διοικητικών βαθμίδων (administrative layers). Μια προφανής συνέπεια είναι ότι τα στελέχη υπηρεσιών πρέπει να διερευνήσουν διεξοδικά αν τα παραπάνω οφέλη υπερτερούν των ωφελειών από τη συγκέντρωση πόρων, που είναι το χαρακτηριστικό γνώρισμα της λειτουργικής δομής (functional structure). Ωστόσο, ενώ οι επικαλυπτόμενες εργασίες και τα περιττά επίπεδα διοικητικής λειτουργίας μπορούν να εντοπιστούν εύκολα, η μείωση του χρόνου προετοιμασίας ενδέχεται να είναι πιο δύσκολο να εντοπιστεί και να ποσοτικοποιηθεί πριν από τη μετάβαση σε κυψελοειδή δομή. Για το λόγο αυτό, καθίσταται κρίσιμο για τα στελέχη υπηρεσιών να δοκιμάζουν τυχόν αλλαγές σε μικρότερη κλίμακα πριν από την υλοποίηση τους στον ευρύτερο οργανισμό, χρησιμοποιώντας το πλεονέκτημα που έχουν, έναντι των ομολόγων τους στη μεταποίηση, να αναδιαμορφώσουν πολύ ταχύτερα και με μικρότερο κόστος τη διάταξη των υπηρεσιών. Ακόμα πιο σημαντικό είναι ίσως το γεγονός ότι τα στελέχη υπηρεσιών πρέπει να εξαντλήσουν όλες τις πιθανές βελτιώσεις στην υφιστάμενη λειτουργική δομή πριν ολοκληρώσουν τη μετάβαση σε κυψελοειδή δομή εργασίας. Η ανάλυσή μας ανέδειξε ότι κανόνες προτεραιοποίησης που ελαχιστοποιούν την ανάγκη προετοιμασίας μπορούν να έχουν πιο σημαντικά οφέλη στη λειτουργική παρά στην κυψελοειδή δομή.

Απόδοση των εργαζομένων υπό συνθήκες πίεσης. Οι δυσμενείς επιπτώσεις του φόρτου εργασίας και της υπερβολικής πίεσης στους εργαζομένους έχουν μελετηθεί στο παρελθόν, ωστόσο, όχι στην περίπτωση κυψελοειδών δομών εργασίας. Τα αποτελέσματά μας υποδεικνύουν ότι ο χρόνος και η ποιότητα των εργασιών δυσχεραίνονται όταν οι εργαζόμενοι βρίσκονται υπό την πίεση φόρτου εργασίας. Η συμπεριφορά τους γίνεται όλο και πιο δυσλειτουργική, ειδικά σε συστήματα με σημαντικά σημεία συμφόρησης (bottlenecks). Σύμφωνα με προηγούμενες έρευνες στον τομέα της μεταποίησης, τα αποτελέσματά μας υποδηλώνουν ότι η υιοθέτηση της κυψελοειδούς δομής πρέπει να αποφεύγει τη δημιουργία σημείων συμφόρησης. Σε αντίθεση όμως με προηγούμενες μελέτες, τα αποτελέσματά μας δείχνουν ότι η δυσλειτουργική συμπεριφορά των εργαζομένων (λόγω αύξησης του φόρτου εργασίας) απαιτεί ιδιαίτερη προσοχή στα συστήματα υπηρεσιών, καθώς μπορεί να δυσχεράνει τη λειτουργία του συστήματος ταχύτερα και σε μεγαλύτερο βαθμό. Ως εκ τούτου, τα στελέχη υπηρεσιών πρέπει να δημιουργήσουν μηχανισμούς που να παρέχουν ορατότητα και να επιτρέπουν την προληπτική και ταχεία επανεξισορρόπηση του φόρτου εργασίας (π.χ. ορίζοντας όρια στις ουρές αναμονής που μόλις ξεπεραστούν ενεργοποιούν την πραγματοποίηση ήδη καθιερωμένων αναδιατάξεων των διαθέσιμων πόρων). Τα στελέχη υπηρεσιών πρέπει επίσης να γνωρίζουν ότι ενδέχεται να χρειαστούν πρόσθετες επενδύσεις για την ανάπτυξη αυτών των μηχανισμών (π.χ. να αποκτήσουν νέους πόρους ή εξοπλισμό, να επενδύσουν στην ανάπτυξη εργαζομένων πολλαπλής κατάρτισης κ.λπ.).

Ευελιξία των εργαζομένων. Τα αποτελέσματα της παρούσας έρευνας επιβεβαιώνουν αυτά προηγούμενων ερευνών ότι ενώ ο χρόνος ολοκλήρωσης μιας υπηρεσίας βελτιώνεται από την υιοθέτηση κυψελοειδών δομών, η αρχική αναμονή στο σύστημα επιδεινώνεται. Τα αποτελέσματα δείχνουν επίσης ότι η αύξηση της αρχικής αναμονής μπορεί να μειωθεί με τη χρήση εργαζομένων πολλαπλής κατάρτισης (cross skilling). Επομένως, η ευελιξία του εργατικού δυναμικού θεωρείται βασική κινητήρια δύναμη για τον μετριασμό των πιθανών αρνητικών επιπτώσεων από την υιοθέτηση κυψελοειδών δομών εργασίας, όπως η αυξημένη αρχική αναμονή και η έλλειψη ευελιξίας σε τυχόν αλλαγές ζήτησης του προϊοντικού μίγματος. Τα στελέχη υπηρεσιών πρέπει επίσης να διερευνήσουν πιθανούς περιορισμούς στην ανάπτυξη των δεξιοτήτων των εργαζομένων για την εκτέλεση μιας σειράς καθηκόντων. Τυχόν περιορισμοί όπως κανονιστικοί (π.χ. περιορισμένη πρόσβαση σε πληροφορίες πελατών από εξωτερικούς συνεργάτες λόγω εμπιστευτικότητας), τεχνικοί (π.χ. ανεξάρτητες πλατφόρμες που «δεν μιλούν» μεταξύ τους) ή χρόνου και χρηματοδότησης (π.χ. για την απόκτηση και διατήρηση πολλαπλών δεξιοτήτων) μπορεί να αποτρέψουν την πολλαπλή κατάρτιση. Τα στελέχη υπηρεσιών πρέπει επίσης να γνωρίζουν και να εφαρμόζουν τεχνικές που ενισχύουν οφέλη της πολλαπλής κατάρτισης με τη μικρότερη δυνατή επένδυση (Hopp και Van Oyen, 2004).

Αλληλεπιδράσεις και συνεργασία μεταξύ εργαζομένων. Με βάση των παρατηρήσεών μας στο πεδίο εργασίας, καταλήξαμε στο συμπέρασμα ότι διαχωρίζοντας εργασίες υψηλής εξειδίκευσης έχει ως αποτέλεσμα αυξημένες αλληλοεπιδράσεις μεταξύ ρόλων, καθώς η ποιότητα του αποτελέσματος της εργασίας των εργαζομένων θα βαίνει μειούμενη λόγω του αυξημένου φόρτου εργασίας. Βάσει προηγούμενων ερευνών (Swank, 2003), η ενσωμάτωση εξειδικευμένων λειτουργιών σε ευρύτερες μονάδες (χαρακτηριστικό της κυψελοειδούς δομής εργασιών) μπορεί να αποφέρει σημαντικά οφέλη όπως η μείωση των αλληλοεπικαλύψεων, η ικανότητα των εργαζομένων να εκτελούν περισσότερα καθήκοντα, καθώς και η συνεχής βελτίωσης και καινοτομία, ως αποτέλεσμα της ανταλλαγής γνώσεων και μάθησης μεταξύ επαγγελματιών από διαφορετικούς κλάδους (Frei, 2008).

Δεδομένου ότι ορισμένοι επαγγελματίες μπορεί να αντισταθούν στην απώλεια της λειτουργικής τους αυτονομίας λόγω της ένταξής τους σε κυψελοειδές δομές εργασίας (Young *et al.*, 2004), το θέμα της επιλογής του κατάλληλου βαθμού ολοκλήρωσης καθίσταται κρίσιμο στο σχεδιασμό υπηρεσιών. Για παράδειγμα, στο περιβάλλον που ερευνήσαμε, η κυψελοειδής δομή φαίνεται κατάλληλη αλλά υπό ορισμένες προϋποθέσεις. Σε πιο εξειδικευμένα επαγγελματικά περιβάλλοντα, η μείωση της επαγγελματικής αυτονομίας μπορεί να έχει πιο σοβαρές επιπτώσεις στη δημιουργικότητα και την ποιότητα. Τα στελέχη υπηρεσιών πρέπει να επιλέξουν τον κατάλληλο βαθμό ολοκλήρωσης, σεβόμενοι τις ατομικές προτιμήσεις των εξειδικευμένων εργαζόμενων.

Συνοπτικά, τα μοντέλα προσομοίωσης που αναπτύξαμε δείχνουν ότι η αντιμετώπιση προβλημάτων ποιότητας στην πηγή τους και η χρήση κυψελοειδούς δομής εργασίας σε ένα περιβάλλον υπηρεσιών μπορεί να έχει σημαντικές θετικές επιπτώσεις στην απόδοση του συστήματος, υπό ορισμένες προϋποθέσεις. Τα αποτελέσματα καταδεικνύουν επίσης ότι οι οργανισμοί παροχής υπηρεσιών πρέπει να αντιμετωπίσουν μοναδικές προκλήσεις προερχόμενες κυρίως από τη συμμετοχή των πελατών στην παραγωγική διαδικασία και την τάση των εξειδικευμένων υπαλλήλων προς την αυτονομία. Από την άποψη της καθολικής δυνατότητας μεταφοράς της ΛΠ στις υπηρεσίες, καταλήγουμε στο συμπέρασμα ότι ενώ είναι λογικό για τον κλάδο των υπηρεσιών να υιοθετήσει βασικές αρχές και στοιχεία της ΛΠ, θα πρέπει αυτά να τα προσαρμοστούν και να μετεξελιχτούν σε πρακτικές και νέα μοντέλα τα οποία είναι προσαρμοσμένα στις ειδικές σχετικές απαιτήσεις και χαρακτηριστικά. Για να επιτευχθεί αυτή η επιδίωξη, είναι απαραίτητο για τους οργανισμούς παροχής υπηρεσιών να αναπτύξουν ικανότητες: εντοπισμού των πραγματικών αιτιών των προβλημάτων, ανίχνευσης πρόδρομων σημάτων χαμηλής απόδοσης, καθώς και ταχύτατης απόκριση στις αλλαγές στο περιβάλλον.

Τέλος, σημειώνουμε ότι τα παραπάνω συμπεράσματα προήλθαν από πειράματα που πραγματοποιήθηκαν σε περιβάλλον παροχής χρηματοπιστωτικών υπηρεσιών. Ωστόσο, θεωρούμε ότι είναι σχετικά και μπορούν να συνεισφέρουν στην επίλυση προβλημάτων ποιότητας και οργάνωσης και σε άλλα περιβάλλοντα υπηρεσιών όπου το κύριο αντικείμενο επεξεργασίας είναι η πληροφορία και οι άνθρωποι (τόσο πελάτες όσο και εργαζόμενοι). Χαρακτηριστικά παραδείγματα είναι η υγεία (επείγοντα περιστατικά), ο τομέας ασφαλιστικών υπηρεσιών (επεξεργασία ασφαλιστικών υπηρεσιών), καθώς και γενικές υποστηρικτικές εργασίες ανεξαρτήτως τομέα (τηλεφωνικά κέντρα, μονάδες διαχείρισης ανθρώπινου δυναμικού και τμήματα λογιστικής και πληροφορικής).

Abstract

The fierce competition among service providers and the on-going growth in demand for services, due to demographic changes and advancements in technology, makes the need for improving the productivity in services more relevant than ever before. Traditionally, service companies have been looking at their manufacturing counterparts for sources of inspiration to improve operations. As such, the undisputed success of the Toyota Motor Company has led academic researchers and business practitioners to study the Toyota Production System and the associated movement of Lean Manufacturing in an effort to decode it and transfer its concepts, strategies and methods to different environments. Today, almost twenty years after the introduction of the term *Lean Service* by Bowen and Youngdahl (1998), there are still questions regarding its applicability. In this dissertation we shed light in aspects of the following research question: *to what extent some important LM concepts can be adopted and adapted in service environments?*

To do so, we first examine the differences between manufacturing and services and the underlying challenges. Subsequently, we review the historical evolution of lean manufacturing its key components, impact and the aspects that have made this approach revolutionary. Finally, we critically review three distinct streams of lean in services. In particular, we review a) the relevance, from the conceptual standpoint, of the lean concepts in services (applicability), b) the lean practices that have been implemented in various service sectors and functions (transferability), and c) the conditions to continuously improve lean practices in service organizations (sustainability). Utilizing the above analysis, we identify ten gaps that are deemed pivotal for generalizing lean in services and focus on four of them. In particular, we clarify the essence and limitations of lean in services, we provide a universal framework for classifying services, and examine the applicability of two of the most well-known lean concepts (quality at the source and cellular work structure) in a highly complex service environment.

Overall, our findings indicate that these two concepts are relevant for services under certain conditions. In particular, we have developed simulation models in financial services and used them to test these concepts under various conditions. The insights gained from the current research are relevant to other *information and people-intensive* service environments, in which the main objects of transformation are information, customers and employees. The results suggest that by addressing quality issues at source and by using a cellular arrangement in a service setting may have significant positive effects on system performance, if some conditions

apply. The results also show that service managers in addition to the challenges faced in manufacturing (e.g. trade-offs between different layouts), they have to address unique challenges driven primarily by customers participating in service production and the propensity of knowledge-intensive employees to prefer professional autonomy. From the universal transferability standpoint, we conclude that while it makes sense for service organization to adopt essential principles and elements of lean, they will have to ultimately adapt and evolve them in practices and new models better suited to their unique environment and challenges. To do so and continuously improve, it is essential for service organizations to develop the dynamic capabilities of identifying the real causes of problems, sensing signals of weak performance and responding rapidly to changes in the environment.

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

1.1 Background and motivation

The service sector is currently dominating world economies both in terms of relative share of Gross National Product (GNP) and employment (number of jobs). In the United States (U.S.) for example, probably the most advanced economy in the world, over 85% of GNP and employment was attributed to service sectors in 2007 (Apte *et al.*, 2012). The transition from the *physical (agriculture, manufacturing)* to the *service* and eventually the *information and knowledge* intensive economy is dated back to the early decades of the twentieth century and has been encountered in every major economy (Apte and Nath 2007; Apte *et al.* 2008, 2012; Karmarkar *et al.*, 2015). By 1956, the number of employees working in white-collar jobs in the U.S. outnumbered those working in blue-collar jobs (Apte *et al.*, 2008), while in 2006 the service sector accounted for approximately 83% of the working population (Chase and Apte, 2007).

Similarly, in terms of contribution to the economy, the share of the service sector in total GNP in the U.S., increased substantially from 46% in 1967 to 56% in 1992 to 63% in 1997 and to 85% in 2007, while the shares of non-service sectors declined correspondingly (Apte and Nath, 2007; Apte *et al.*, 2012). Service industries displaying the highest growth rates included business, medical and educational services. Similar trends are being observed globally. According to a recent report by the Organization for Economic Cooperation and Development (OECD, 2017), the contribution of each sector, namely agriculture, manufacturing, services and other activities (construction, utilities), to the total value added[1] has changed considerably over recent decades (Figure 1.1). The share of agriculture is now relatively limited in almost all OECD countries. The share of manufacturing has also fallen, while services now account for well over 60% of total gross value added in most OECD countries.

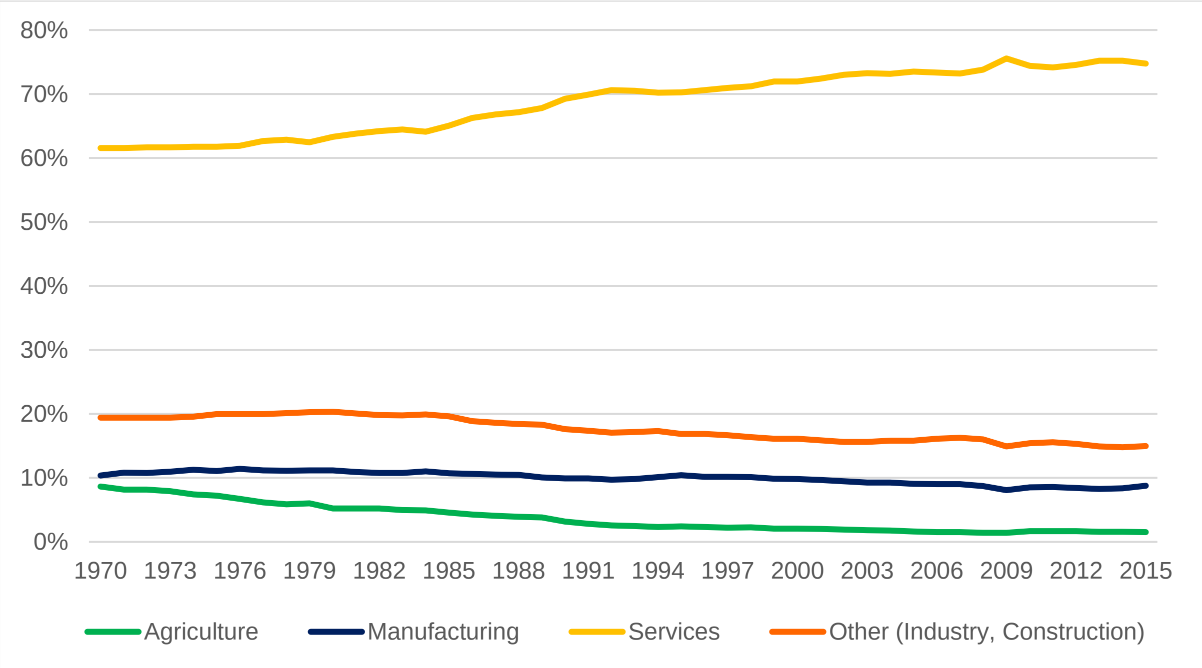


Figure 1.1: Value added by activity, % of value added, 1970 – 2015, OECD countries (OECD, 2017)

However, despite the importance of the service sector and the continuous efforts to *industrialize* services through information technology, it seems that productivity of services has been lagging manufacturing. In the Euro area countries, for example, a mix of advanced economies with different characteristics, manufacturing productivity has been consistently

[1] Value added is the contribution of labor and capital to production. Value added by activity breaks down the total value added by sector. The shares of each sector are calculated by dividing the value added in each sector by total value added.

higher compared to service sector productivity (Figure 1.2). The latter has experienced a declining trend in 1995-2015, with a major drop in 2007-09 as a result of the global financial crisis. Productivity of the manufacturing sector, although dropped even further during the crisis, it appears to have recovered considerably from 2013 onwards (OECD, 2017).

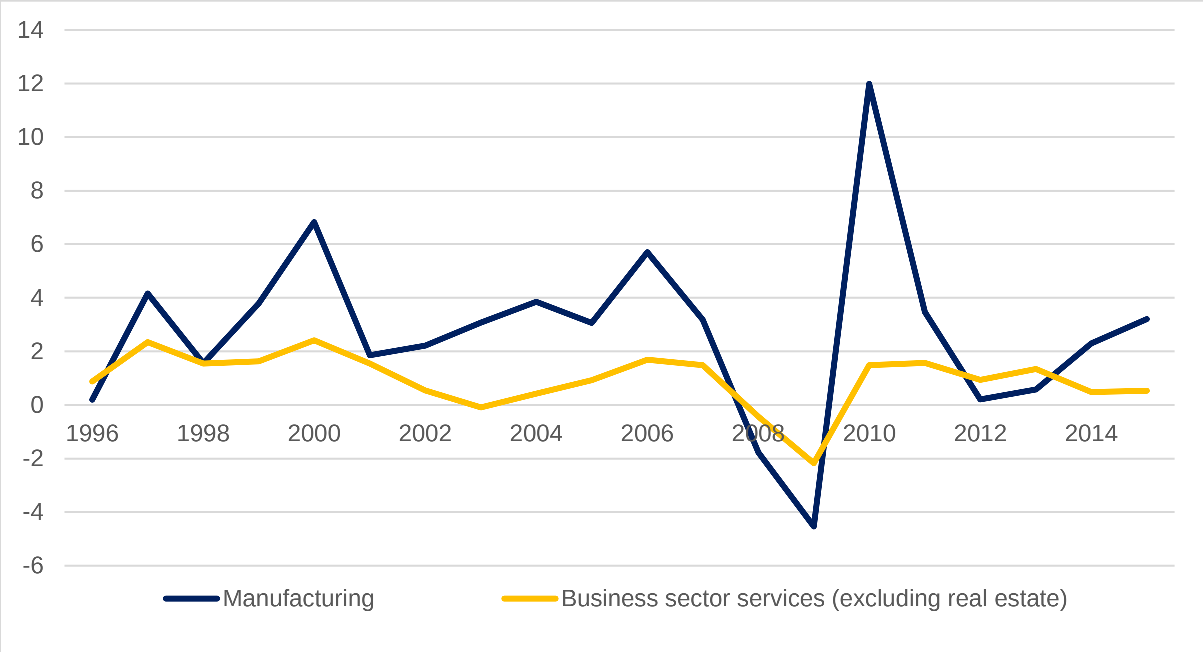


Figure 1.2: Gross value added per hour worked, % Annual growth/ change, 1996 – 2015, Eurozone 19 countries (OECD, 2017)

Furthermore, service organizations are subject to external pressures to reduce costs and improve quality, while the future demand for services is expected to grow. The forces driving these changes include:

- *Changing demographics*, such as the changing working population (e.g. increasing female population joining the workforce) and greater life expectancy (Demirkan, *et al.*, 2011), which are expected to increase the demand for domestic and healthcare services;
- *Rising consumer expectations* will increase pressure for new, more sophisticated, customizable, and at a reasonable cost on-demand services in healthcare, education and business services (Krishnamurthy, 2007);
- *Technological advancements* allow the introduction of new disruptive e-services which intensify the competition in all sectors, manufacturing as well as service (e.g. Uber in transportation, Fintech companies in financial services, Airbnb in hospitality industry, etc.);

- *Servitization* is expected to increase demand for services, as more manufacturing firms will seek to improve their competitive position by integrating services into their core value offering (Chase and Apte, 2007).

Not surprisingly the above changes are expected to increase demand as well as the need for more efficient and effective services. Therefore, identifying methods to improve productivity in services represents one of the main challenges in operations management in the post-industrial era (Ellram *et al.*, 2004; Malmbrandt and Ahlstrom, 2013). Traditionally, service companies have been looking at their manufacturing counterparts for sources of inspiration to improve their operations (Apte and Goh, 2004; Chase and Apte, 2007). One of the most cited examples in the history of manufacturing management is Toyota Motor Company, especially its production system and the associated movement of Lean Manufacturing (henceforth LM). The rise of Toyota from an insignificant player in the automotive market in 1950 to one of the largest automotive manufacturers in the word in the 1990s (Hopp and Spearman, 2001), and eventually to the largest in 2007 (New, 2007), urged academic researchers and business practitioners to research and apply LM concepts in other environments.

Consequently, it is believed that every major organization, even in traditional service industries such as healthcare and financial services, has been exposed to some of the LM concepts and experimented with at least one lean initiative over the last twenty years (Hopp, 2013). However, as it is the case in manufacturing, transferring and sustaining lean concepts outside the automotive industry with similar success to Toyota is not straightforward for a number of reasons. First, services are *vastly diverse*, with *highly distinctive operational* characteristics covering a wide range of sectors from healthcare, to financial and hospitality services. Second, services encompass *unique elements* not found nor addressed in manufacturing, such as *customer participation*[2] and *server dependency* during service delivery, as well as the *intangible nature* of service output. Third, services are *inherently variable* due to these unique elements, and the uncertainty and unpredictable variations *emerging* in *service supply chains*; that is, several professionals from different fields and entities intervene to respond to a customer request (Harvey, 2016). Therefore, the transferability of LM concepts to service systems is challenging and cannot rely strictly on the related work performed in manufacturing.

[2] Also known as customer interaction, involvement, engagement, contact

The current work investigates the application of LM concepts in services. Since this topic is quite broad involving several service sectors and disciplinary areas, we focus on specific gaps, following an extensive review of manufacturing and service literature. These gaps shed light on specific aspects related to the extent that some important LM concepts can be adopted and adapted to service environments. Most importantly, addressing these gaps sets the foundation for creating a framework for lean services, which will help organize the existing knowledge and inspire further research on the topics left outside the scope of this dissertation.

1.2 Unique service challenges and differences from manufacturing

To investigate the extent that LM concepts can be adopted and adapted in services, it is critical to understand first a) the similarities and differences between manufacturing and services, and b) the challenges faced by various service organizations, and the implications of these challenges in service design and management.

If we examine services from the sectorial point of view, it seems that the number of industries (sectors) classified as services is significant and diverse. For example, according to the Bureau of Economic Analysis of the U.S. Department of Commerce (BEA), services include all industries except agriculture, manufacturing, mining, construction and utilities, from transportation and warehousing, to arts, accommodation and government services. Service sectors differ significantly from each other in terms of size, scope, operational characteristics and challenges. The list of the main groups of service sectors (Figure 1.3), illustrates this diversity, and highlights major service sectors in terms of Gross Output[3] (BEA, 2017).

It seems that there is no common definition for services in the relevant literature, despite the valuable contributions from researchers of various fields, such as economics, marketing and operations. For example, according to Hill's early definition (1977): "*A service may be defined as a change in the condition of a person, or of a good belonging to some economic unit, which is brought about as the result of the activity of some other economic unit, with the prior agreement of the former person or economic unit*". Vargo and Lusch (2004) defined service as "*the application of specialized competences (skills and knowledge), through deeds, processes, and performances for the benefit of another entity or the entity itself (self-service)*",

[3] Gross output represents the market value of an industry's production and differs from value added, which represents the contribution of the industry's labor and capital to its gross output and to overall GDP.

while Johnston and Clark (2008) state "*the combination of outcomes and experiences delivered to and received by a customer*". The common element in most service definitions is that services are considered to be *activities* or *processes*. For example, Gronroos (1988) states that "*services are activities rather than things*", while Silvestro *et al.*, (1992), state that in services "*they do things for you. They do not make things*".

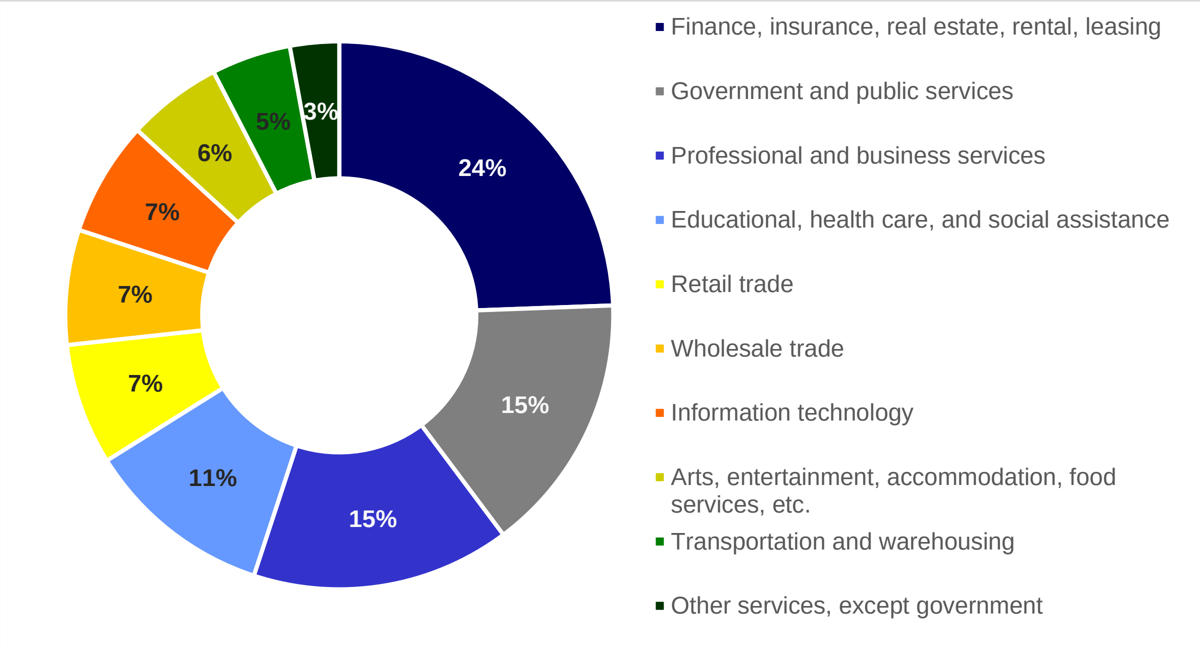


Figure 1.3: Gross Output per service sector, %, 2015, U.S.A. (BEA, 2017)

Some notable characteristics and contributions clarifying the nature of services, include:

- *Traditional Service Characteristics*: *inseparability* of production and consumption, according to which services are usually created and consumed simultaneously; *perishability* of service capacity, if capacity is not used at the time it is available (e.g. empty airline seats); *intangibility* as far as the output of the service is concerned; and *heterogeneity* since the quality of the service can vary depending on the provider, the customer, and other factors (Zeithaml, Parasuraman, and Berry, 1985)
- *Customer (and information) as the dominant object(s) of transformation*, with material transformation playing a lesser role (Morris and Johnston, 1987). *Customer participation* during the creation of a service is considered to be the main differentiator between services and non-services, as well as the root cause for most of the challenges faced in services, as suggested by the *Customer Contact Theory* (Chase, 1978) and the *Unified Service Theory* (Sampson and Froehle, 2006). The role of the customer in service delivery highlighted the importance of experience

and the *experience economy* (Pine and Gilmore, 1998), in the sense that experience is equaly important as the products and services.

- *Server Dependency*, suggesting that the role of the service employee is critical, since several aspects of the service, such as speed, quality and eventually profitability are heavily dependent on the servers (Heskett *et al.*, 1994).
- *Variability Reduction Theory*, including various approaches to address variability introduced by customers, such as arrival, request, capability, effort and subjective preference variability (Frei, 2006)
- *Service Classifications*, including numerous classification schemes based on distinctive attributes resulting typically to the creation of a two–by–two matrices, where each axis corresponds to one of the two attributes (e.g. Maister and Lovelock, 1982; Schmenner, 1986)
- *(Professional) Service Supply Chains*, that is, organized *or emerging* sequences of professional, clerical, and technical services that unfold in *service episodes* (situations) to provide specific results, such as producing a financial product, designing a house, or a medical procedure to replace a hip (Harvey, 2016)

As mentioned in the introduction, the first step to assess the relevance of LM concepts in services, is to understand the differences between manufacturing and services and the underlying challenges. Given the richness of past research, we leverage key previous concepts to compare, in a systematic way, various service archetypes against manufacturing in a series of characteristics and managerial challenges. This comparison is presented in Table 1.1. The table comprises of *columns*, representing the various service archetypes (and manufacturing), and *rows*, representing distinctive characteristics and managerial challenges.

In terms of service archetypes, we enhance Schmenner's (1986) seminal work (*Service Factory, Mass Service, Service Shop, and Professional Services*), with two additional archetypes: *Self-services*, including *e-services*, which have become very popular with the extended use of the internet, and *Service Supply Chains* including interactions and cooperation between various service organizations, analogous to physical supply chains.

Each service archetype is assessed against manufacturing based on four characteristics deemed critical in the service literature (Schmenner, 1986; Correa *et al.*, 2007)[4]: *customer interaction and service customization*, *labor intensity*, *stockability* and *simultaneity of production and consumption*. Furthermore, the challenges derived from these characteristics are mapped in six distinct managerial areas, typically found in the service operations literature (Fitzsimmons and Fitzsimmons, 2005; Hopp, 2013): *service package and process design, buffer management, scheduling and queueing, quality management, performance management, people and organization management*. The assessment is extended to these challenges as well.

It is noted that for manufacturing we have considered generic trends that are common in most industries and production systems. It is also noted that each service archetype can feature a standalone service (e.g. Uber in transportation) or a mix of different service types within an organization (e.g. banking services including e-banking) (Schmenner, 2004). Similarly, service supply chains are a mix of service archetypes, a network of interacting professionals (plus overlapping employers, professional bodies, etc.) from different organizations cooperating to provide specific results (Harvey, 2016).

In reviewing the results of Table 1.1, we conclude that service managers face quite different challenges from their manufacturing counterparts. For example, as the complexity of *customer interaction and customization* increases, the need for more flexible processes and sophisticated systems to assess service quality and performance increases as well. Service managers face also different challenges in terms of managing their resources. Examples include gaining employee loyalty, transferring skills and imposing controls and behaviors, all of which are more pronounced in professional service settings.

The results also suggest that service managers lose some of the available options to level demand and control service quality. For example, when the *degree of stockability* is low, the available buffers to cope with variability are capacity (i.e. provide resource availability when needed) and time (i.e. adjust service delivery time as needed) (Correa *et al.*, 2007; Hopp, 2013). The latter is typically used by service managers to level demand when *capital intensity* is high and asset capacity fixed (i.e. influencing customer behavior with revenue management and reservation systems).

[4] The characteristic *Degree of ease in performance assessment* from Correa *et al.* (2007), has been replaced by *Capital vs labor intensity* suggested by Schmenner, (1986), since the former has been considered a managerial area impacted and not a generic, distinguishing characteristic of services

In some other instances, when the *degree of simultaneousness* is high, customers cannot easily assess the quality of service before experiencing it, while service managers lose some options to control quality. For example, finished product quality control is not possible. Therefore, self-inspection and quality controls embedded during service delivery are critical.

Table 1.1: Characteristics and challenges: service archetypes versus manufacturing

CR: Characteristic (CR) or, Challenge (CL)	Manufacturing	Self-service	Service Factory	Mass Service	Service Shop	Professional Services	Service Supply Chains
Examples	• Automotive, semiconductor, steel manufacturers, etc.	• ATM, e-services, such as e-banking, e-shopping	• Airlines, Hotels, Transportation, Resorts	• Retailing, Wholesaling, Schools, Cleaning and Laundry	• Hospitals, Repair Services, high-end Restaurants	• Doctors, Lawyers, Architects, Accountants, Consultants	• A patient with a back-pain episode, a child under social protection case
CR: Customer interaction and service customization	• Customer does not interact with any aspect of the production process. A few exceptions exist such as furniture assembled by the customer	• Customer executes the service hence no contact with human service providers • Well-defined, less-variable processes with standard customization options	• Low degree of interaction and information complexity (richness, amount, details) • Well-defined, less-variable processes with standard customization options	• Low degree of interaction and information complexity • Well-defined, less-variable processes with standard customization options	• Highly variable interaction and information complexity, typically following a diagnosis, inference and treatment • Variable service package customization	• Highly variable interaction and information complexity, typically following a diagnosis, inference and treatment • Variable service package customization	• Flows evolve (or emerge) in unpredictable yet nonrandom ways, in a network of interacting professionals from different entities • Typically, there is no standard service package per se
CR: Capital vs labor intensity	• Typically, very high capital costs (investments and maintenance) are required to manufacture products • Labor 'Professional' skills and behavior typically driven by an external body of knowledge	• High capital costs are often required to offer the self-service infrastructure • Labor is provisioned by the customer, and certain skills to perform the service are assumed	• High capital costs are required to offer the service, with labor costs proportionally less significant • Labor 'Professional' skills and behavior typically driven by an internal body of knowledge	• High labor costs are required to offer the service, with capital costs proportionally less significant • Labor 'Professional' skills and behavior typically driven by an external body of knowledge	• High capital costs are required to offer the service, with labor costs proportionally less significant • Labor 'Professional' skills and behavior need deep domain knowledge, typically driven by an external, large body of knowledge	• High labor costs are required to offer the service, with capital costs proportionally less significant • Labor 'Professional' skills and behavior need deep domain knowledge, typically driven by an external, large body of knowledge	• High labor costs are required to offer the service, with capital costs proportionally less significant • Labor 'Professional' skills and behaviors often require frequent interactions with other professionals to gain necessary information and work-related knowledge
CR: Degree of stockability	• High degree of stockability, since inventories of all types exist and can be built depending	• High degree of stockability, since information-intensive services can be inventoried	• Low degree of stockability, since it is impossible to stock the requested service in	• High degree of stockability in cases where physical goods are part of the core service	• Low degree of stockability, since it is impossible to stock the requested service in	• Low degree of stockability, since it is impossible to stock the requested service in	• Low degree of stockability, since it is impossible to stock the requested service in

CR: Characte-ristic (CR) or, Challenge (CL)	Manufacturing	Self-service	Service Factory	Mass Service	Service Shop	Professional Services	Service Supply Chains
	on the manufacturing strategy (make-to-order, make-to-forecast, etc.)	electronically (e.g. balance of accounts status stored in a bank's database)	anticipation of demand • Inventories can be present, but typically they are not related to the core service offering	offering (e.g. inventories in retail) • Low degree of stockability in cases of pure-service offering (e.g. teaching services)	anticipation of demand • Inventories can be present, but typically they are not related to the core service offering	anticipation of demand	anticipation of demand
CR: Simultaneity of production and consumption	• Low degree of simultaneousness, since consumption is typically separated from production	• High degree of simultaneousness, since services are consumed as produced (e.g. automated answering system that provides standard information)	• High degree of simultaneousness, since production and consumption are often nearly simultaneous	• Consumption and production can be nearly simultaneous, but periods elapsed between production and consumption can also be long (e.g. when physical goods are part of the core service offering as in retail)	• High degree of simultaneousness, since production and consumption are often nearly simultaneous	• High degree of simultaneousness, since production and consumption are often nearly simultaneous	• High degree of simultaneousness, since production and consumption are often nearly simultaneous
CL: Service package and process (facility) design	• Capital (e.g. selection of location and equipment, maintenance) and technology (e.g. technology selection, delivery channels) decisions are primary managerial concerns • Process flexibility and facility layout may depend on product specifications and type of production system	• Capital and technology decisions are primary concerns • Challenge to design standard services that can be performed by all customers independent of their skills, preferences, etc. • Challenge to incorporate relationship aspects in customer touch-point and experiences	• Capital and technology decisions are primary concerns • Focus on standardization of service packages rather than higher process flexibility • Challenge to incorporate relationship aspects in customer touch-point and experiences • Attention to physical surroundings (when	• Capital and technology decisions could be primary concerns • Focus on standardization of service packages rather than higher process flexibility • Challenge to incorporate relationship aspects in customer touch-point and experiences • Attention to physical surroundings and	• Capital and technology decisions are primary concerns • Challenge to balance between standardization and process flexibility • Challenge to react to customer intervention and manage variable process inputs • Attention to physical surroundings and coordination with back-office activities	• Capital and technology decisions could be primary concerns • Focus on higher process flexibility to conform to specifications of individual customers • Challenge to react to customer intervention and manage variable process inputs • Attention to physical surroundings and	• Capital and technology decisions could be primary concerns • Challenge to design and establish controls (formal norms, standards, control systems and cultural influences) in the interactions of several professionals from different fields and entities, given their differences in professional autonomy,

CR: Characte-ristic (CR) or, Challenge (CL)	**Manufacturing**	**Self-service**	**Service Factory**	**Mass Service**	**Service Shop**	**Professional Services**	**Service Supply Chains**
		• Challenge to coordinate and align service offerings across different delivery channels and technologies	customers are physically present) and coordination with back-office activities	coordination with back-office activities		coordination with back-office activities	preferences and aversion to controls
CL: Buffer management	• Coping with variability is mainly achieved through inventory, capacity and time buffers • Focus is on bringing inventories at a level that maximizes the firm's long-term profitability	• Coping with variability is mainly achieved through inventory (e.g. replenishment of vendor machines) and capacity buffers (e.g. adequate infrastructure capacity to provide on-demand e-services)	• Coping with variability is mainly achieved through capacity and time buffers • In cases in which capacity is inflexible, the focus is on managing demand to level peaks and to promote off-peak times (e.g. price incentives in hotels)	• In cases in which physical goods are part of the core service offering, the focus is on bringing inventories at a level that maximizes the firm's long-term profitability • In cases of pure-services, building flexible and low-cost resource capacity is critical (cross-skilled, part-time labor)	• Coping with variability is mainly achieved through capacity and time buffers • Building flexible and low-cost (resource) capacity is critical, (cross-skilled, part-time labor) • Demand also needs to be managed to level peaks (e.g. reservation systems)	• Coping with variability is mainly achieved through capacity and time buffers • Building flexible and low-cost (resource) capacity is critical, but also challenging (e.g. cross-skilling in professionals) • Demand also needs to be managed to level peaks (e.g. reservation systems)	• Coping with variability is mainly achieved through capacity and time buffers • Challenge to co-ordinate and influence (quasi) autonomous economic agents
CL: Scheduling and Queueing	• Queuing of materials may matter and is handled by production planning and scheduling • The psychology of queues, however, is not relevant	• Given that self-services are designed to be executed by the customer on-demand, scheduling and psychology of queues usually have little relevance	• Given fixed capacity, scheduling workforce and service delivery is relatively more important than in other business • In cases in which people are involved, management and psychology of queues are important • In non-physical queues, the queue	• Given limited buffers, scheduling workforce and service delivery is critical • In cases in which people are involved, management and psychology of queues are important • In non-physical queues, the queue length is not visible to customers, hence	• Given that complex services often have uncertain and highly variable completion times, scheduling workforce and service delivery are critical and challenging • Given that queuing involves people, management and psychology of queues are important	• Given that complex services often have uncertain and highly variable completion times, scheduling workforce and service delivery are critical and challenging • Given that queuing involves people, e management and psychology of queues are important	• Analogous techniques to supply chain management (information transparency, sharing resources, etc.), can be used to coordinate various economic agents • Management and psychology of queues are important

CR: Characte-ristic (CR) or, Challenge (CL)	Manufacturing	Self-service	Service Factory	Mass Service	Service Shop	Professional Services	Service Supply Chains
			length is not visible to customers, hence they need to rely to the information provided by the service firm (if any)	they need to rely to the information provided by the service firm (if any)	• In non-physical queues, the queue length is not visible to customers, hence they need to rely to the information provided by the service firm (if any)	• In non-physical queues, the queue length is not visible to customers, hence they need to rely to the information provided by the service firm (if any)	• In non-physical queues, the queue length is not visible to customers, hence they need to rely to the information provided by the service firm (if any)
CL: Quality management	• Easy to assess quality in advance, as it is determined by the conformance to well-defined specifications (although some products such as drugs and cars can be assessed by non-objective criteria, such as perceived quality and image) • Full set of quality control options is available (end-product, in-process and self-control)	• Quality specifications, customer perceptions and expectations are typically well known • Attention should be given to activities such as customer training and mistake proof mechanisms • Challenge to embed professional judgement in processes and equipment	• Specifications and customer perceptions and expectations are typically well known • Although, end-quality may involve complex aspects like assessing relationship, cooperation, and responsiveness • Emphasis should be given to in-process, self-control and managing expectations	• Quality specifications, customer perceptions and expectations are typically well known • Although, end-quality may involve complex aspects like assessing relationship, cooperation, and responsiveness • Emphasis should be given to in-process, self-control and managing expectations • Managing growth while keeping labor costs low is challenging	• Quality specifications, perceptions, and expectations are often not well defined, so managing them is critical • Challenge to limit heterogeneity caused by workers performing services differently; design sophisticated controls that consider professional judgement and experience • Emphasis should be given to in-process, self-control and managing expectations	• Professional service quality and standards is often challenging to establish, communicate, assess and maintain • Emphasis should be given to in-process, self-control and managing expectations • Implicit parts of the service offering can signal appropriate quality (e.g. firm's reputation, employees' qualifications, etc.) • Managing growth while keeping labor costs low is challenging	• Specifications, perceptions, and expectations are often different between the entities involved • Challenge to establish and maintain service quality, since efforts aimed at enforcement and compliance can be perceived as counterproductive • Emphasis should be given to in-process and self-control
CL: Performance management	• Relatively simple performance assessment system (e.g. productivity	• Relatively simple performance assessment system	• Relatively simple performance assessment system • Some complexity in assessing quality,	• Relatively simple performance assessment system • Some complexity in assessing quality,	• Need for more sophisticated performance assessment approaches, able to	• Need for more sophisticated performance assessment approaches, able to	• Challenge to align different performance assessment

CR: Characte-ristic (CR) or, Challenge (CL)	Manufacturing	Self-service	Service Factory	Mass Service	Service Shop	Professional Services	Service Supply Chains
	measures, efficiency frontiers) • Any complexity in assessing quality, usually resolved by asking the customer directly		usually resolved by asking the customer directly	usually resolved by asking the customer directly	define and measure "soft" (e.g. trust), and "hard" aspects (productivity, efficiency frontiers) • Given high level of worker autonomy, different incentives may be appropriate compared to blue-collar workers (peer recognition, self-advancement, etc.)	define and measure "soft" and "hard" aspects • Given high level of worker autonomy, different incentives may be appropriate compared to blue-collar workers	approaches used by the various entities
CL: People and organization management	• Many layers of management, fairly rigid, following the classic pyramid • Training should focus on performance within specifications and self-inspection • Interpersonal skills are less relevant	• No human service provider is directly involved, except for handling or adjusting rules over time	• Many layers of management, fairly rigid, following the classic pyramid • Training should focus on interpersonal skills, performance within specifications and self-inspection	• Many layers of management, fairly rigid, following the classic pyramid • Training should focus on interpersonal skills, performance within specifications and self-inspection • Challenge to maintain employee welfare (e.g. work life balance)	• Typically, hierarchy is flatter with loose subordinate-superior relationship • Learning is slower, and training should focus on professional judgement, interpersonal skills, and self-inspection • Gaining employee loyalty, welfare and transfer of skills is challenging	• Typically, flat hierarchy with loose subordinate-superior relationship • Learning is slower, and training should focus on professional judgement, interpersonal skills, and self-inspection • Gaining employee loyalty, welfare, transfer of skills and adherence to controls is challenging	• Challenge to coordinate entities with no clear leadership structure, different power in the cooperation and ownership towards the client

Sources: Schmenner (1986, 2004, 2012), Correa *et al.* (2007), Lewis and Brown (2012), Hopp, Iravani and Liu (2009), Hopp (2013), Harvey (2016)

1.3 Research questions, approach and dissertation outline

The above assessment indicates that the more service delivery becomes human dependent (or intellectually-oriented), the wider the gap, in terms of operational challenges, between manufacturing and services. Consequently, it would be reasonable to question whether proven manufacturing methods, such as LM, are relevant or can have similar impact in services.

For example, given that variability reduction is at the core of lean, to what extend standardization in services can be realistic and effective, given that customer inputs and expectations are often non-identical, while service employees resist controls that limit their professional autonomy? Or, if reduction of inventories is the main benefit of LM in the automotive industry, what would be the equivalent benefit in services, given that (typically) inventories do not exist? Or, how to maintain a consistent level of quality, a defining characteristic of LM, when service quality is particularly difficult to define and measure, and employees use it as a buffer to cope with variability (in addition to capacity and time)? Some more practical questions as to the implementation of LM concepts in services may arise as well. For example, how can the well-known LM concepts of *pull* (i.e. pacing work with the rhythm of demand) and *cellular manufacturing* (i.e. organizing resources according to process similarity) be implemented in services, given the challenges in measuring service output, productivity and efficiency frontiers?

These are relevant questions when one considers LM in the context of services. Under the context of the current dissertation, we aim to shed light in aspects of the following research question: "*to what extent some important LM concepts can be adopted and adapted in service environments?"* To do so, we use the assessment of the previous chapter to trace the similarities and differences between manufacturing and services and between services themselves. We also review the LM literature to understand what LM really is, as well as to assess the generality and limitations of LM in services in relation to their unique challenges. This analysis helps us prioritize three research areas which are the main focus of the dissertation.

The first refers to the field of *service science* research and is generic for all services. Given the lack of a widely accepted approach to classify services, we develop a systematic method to determine the principle service attribute, to be considered for service design and management. The remaining two areas focus on two of the most popular LM concepts, *quality at the source* and *cellular manufacturing*. In the former, given the importance of quality in service operations, we quantify the impact of critical failure parameters, and test the efficiency of typical managerial practices used to address failures on key system performance measures. In the latter, we compare the impact of cellular structures against functional structures. In both cases we use discrete event simulation to model the behavior of a typical two-stage service system (front-office, back-office). The findings are validated through respective case studies in the post trade financial services, in the context of a broader lean transformation program (the author was a member of the internal transformation team).

Given the diversity of service sectors, we select a typical system in financial services that delivers low volume-high complexity services, which is equivalent to the traditional job shop in manufacturing. In service typology terms (Schmenner, 1986), the selected environment is positioned in the *Service Shop* archetype, leaning towards the *Professional Service*, since for certain aspects of the service (e.g. investigation and correction of complex queries and errors), high labor intensity and discretion is required. In addition, the main objects of transformation are information, customers and employees, and thus the insights to be gained may be relevant to other similar *information and people-intensive* service environments, such as supporting functions of any organization (e.g. human resource management, finance, IT), or across service sectors (e.g. emergency departments in healthcare, call centers, back-office operations in banking, claims and underwriting in insurance).

Finally, we develop a conceptual *lean service* definition that summarizes insights from past research and the current findings of this dissertation, along with directions for further research.

The structure of the dissertation is summarized as follows:

Chapter 2 reviews the existing literature of LM both in manufacturing and services. The former helps us understand the essence and key components of LM, while the latter is reviewed in terms of: a) *applicability*, i.e. the relevance of LM in services from the theoretical standpoint as well as the limitations and modifications of lean concepts to match the distinctive characteristics of services; b) *transferability*, i.e. the available approaches to implement LM in services, including the scope and sequence of implementation; c) *sustainability*, i.e. the necessary conditions in order to sustain LM in a service organization. The extent of the literature review was considered necessary given the number of different areas involved (service definitions and characteristics, lean in manufacturing and lean in services) in order to identify the relevant gaps in the literature and the focus points of this dissertation.

Chapter 3 focuses on service classification and, in particular, the lack of a widely accepted approach to define and classify the diverse characteristics and nature of services. This work leverages relevant results of service classification systems and identifies the principal attributes to be considered in service management. The tool introduced for this purpose is the Service Attribute-Process Matrix (SAPM), which provides a systematic way to identify key attributes for improving service efficiency and quality as well as attributes that may affect transferability of lean in services.

Chapter 4 studies the operational impact of service quality (failures) on key system performance measures. The results suggest that the adverse impact of failures and rework is minimized when service organizations can detect failures early on, and when they are capable enough to recover from these failures timely and efficiently. In addition, the results illustrate that typical management practices used to address failures (e.g. add capacity, chase demand, off-line processing of failures) have strengths and weaknesses depending on the characteristics of both the service system and of the failures themselves. If this is not taken into consideration, the above managerial practices may lead only to short-term improvements, while the main causes of failures will remain unresolved.

Chapter 5 investigates the appropriateness of cellular work structures for information intensive services under a wide range of conditions. In this study we consider important and unique service characteristics, such as the relationship of operator performance and workload or overwork. The results favor the cellular structure in service environments in which a) significant improvements in key operational parameters may be achieved by introducing work cells; b) no severe bottlenecks exist (well-balanced systems); c) operators are cross-skilled; d) high information dependencies exist amongst tasks. The study concludes by citing important managerial implications that need to be considered before embarking into the establishment of cells.

Finally, Chapter 6 presents the conclusions of this dissertation along with directions for further research. Based on the findings from the literature review as well the managerial implications derived from the simulation experiments, we provide a useful guide that could accelerate the transformation pace and impact for service companies trying to improve their operations. It also organizes the existing body of knowledge and highlights further research opportunities.

1.4 Research contributions of this dissertation

Our contribution to the study of LM concepts in services involves insights in the following areas:

In the area of service science and in view of the lack of a commonly accepted framework to classify and assess services, we propose a new approach, the Service Attribute-Process Matrix (SAPM). SAPM with its six distinct modules and the interdependencies between these modules, provides to service managers the opportunity to anticipate changes, make rapid improvements (by tracing dependent components and reusing same modules) and eventually gain flexibility for mass customization. For service researchers, SAPM provides a *generic modular architecture* for services that can be used as a basis to explore the concept of *modularity in services*, a field that is attracting increasing interest in the wider modularity literature.

In the area of service quality, we introduce a new theoretical framework, the *vicious cycle of failures in service operations*. We explore this cycle, as well as the impact of typical managerial practices to address failures, based on empirical investigation and simulation. We also develop a discrete event simulation model of a typical two-stage system encountered in many service organizations (front-back office). The simulation model and the associated scenarios can be reconfigured easily to investigate failures (and the managerial practices to address them) in other similar and more extensive (n-stage) service systems.

In the area of cellular structures, we provide a detailed description of the applicability and implications of cellular operations in services based on empirical investigation and simulation. We also develop a discrete event simulation model for mapping cellular operations in services. The simulation model embeds the following three aspects through which the behavior of professional actors manifests itself and influences service system performance: a) the way operators react to changes in system's workload and overwork, b) operator flexibility in terms of the array of tasks they can perform, and c) the way operators interact with each other. These aspects of professional behavior have been studied in the past, but not in the context of cellular operations.

Finally, in the area of LM in services, the current dissertation provides a detailed view of *key LM components* found in the literature. This includes a complete catalogue that encompasses sources of inefficiencies, definitions, principles, practices and tools. In this area, we have performed a complete assessment on the applicability of LM concepts in services, based on literature results that can be used as a decision support tool for accelerating the pace and impact of lean transformations in service companies, and also as a reference for the existing body of knowledge for academic researchers.

Chapter 2. Perspectives on the relevance of lean manufacturing concepts in services and key gaps

2.1 Introduction

For the past 50 years, the undisputed success of the Toyota Motor Company has led academic researchers and business practitioners to study the Toyota Production System, in an effort to decode it and transfer its concepts, strategies and methods to similar or different manufacturing environments. In the service sector, the attention to Toyota and the related movement of LM came with some delay compared to manufacturing, even though the role and importance of services in advanced economies has been continuously increasing. Indeed, since the introduction of the *Just-in-time* concept in services in the late 1980s, and the term *Lean Service* (henceforth LS) in the late 1990s (Bowen and Youndahl, 1998), there has been an increased interest to the adoption and adaptation of LM concepts in service industries. Today, almost twenty years after the introduction of LM in services, there are still questions regarding its applicability. This Chapter aims to provide an overview of the academic literature of LM in services, and reveal current gaps, some of which will be addressed in the current dissertation.

To do so, first we review the existing literature regarding LM, with the objective to identify and clarify its *essence and key components*. In particular, we present the historical evolution of LM and its key elements. Subsequently, we discuss the impact of LM to various manufacturing sectors and its limitations. Finally, we summarize the aspects that have made this approach revolutionary. The above analysis sets the platform to assess the applicability of LM concepts in services.

To proceed with this assessment, we distinguish the relevant LS literature in three major streams: *applicability, transferability and sustainability*.

Applicability refers to the relevance of LM concepts to the challenges faced by service organizations, and consequently the limitations or necessary modifications to address those challenges. Specifically, we review the *evolution* as well as the *theoretical and conceptual* contributions in the field of services. Then we clarify *what* constitutes LS in terms of definitions, principles and frameworks, as well as the types of wastes found in services. Finally, we examine *adaptations and extensions of LM concepts* to fit the characteristics of services.

Transferability refers to the implementation of LM in services, as well as the approaches and barriers to implement LM concepts in services. Specifically, we review implementation cases of LM concepts in services and specifically *where* it has been implemented (industry and function perspective) and *what* elements of LM have being implemented (practice perspective) as well as the associated impact on performance. We also present *how* LM concepts can be implemented based on the available approaches in manufacturing and service literature, *where* the implementation can be initiated and the *challenges* to overcome for a successful implementation.

Finally, by *sustainability* we refer to the necessary conditions to sustain lean in an organization. As it will be discussed later, continuous improvement is considered a condition for survival in light of competitive, technological and market pressures. The above review and assessment is followed by a discussion on the relevant gaps in the literature and the focus points of this dissertation.

The remainder of this Chapter is structured as follows: Section 2.2 presents the literature regarding LM. Sections 2.3, 2.4. and 2.5. focus on the topics of applicability, transferability and sustainability of lean in services, respectively, and Section 2.6 discusses the gaps in the literature and the contribution of the current dissertation.

2.2 Lean manufacturing: the paradigm for increased productivity

The history and evolution of LM are well known and have been studied extensively in the past (Ohno, 1988; Monden, 1998; Fujimoto, 1999; Hopp and Spearman, 2001, 2004; Liker, 2004; Papadopoulou and Ozbayrak, 2005; Holweg, 2007; Schonberger, 2007). In the next paragraphs we present a short overview of the evolution of LM, with the objective to identify and clarify its essence and key components. This sets the platform for assessing the applicability, transferability and sustainability of LM concepts in service.

2.2.1 Origins, evolution and components

The origins of LM can be traced in the Toyota Motor Company. In the 1940s, after the Second World War, Toyota began developing a new production system, later known as the *Toyota Production System* (TPS), in an effort to catch up with its American competitors. This development has been enormously successful, contributing to Toyota becoming the largest automotive manufacturer in the word, as well as setting a new paradigm in manufacturing management since the scientific management movement of the 1920s (Hopp and Spearman, 2001). TPS was developed within Toyota and extended to its suppliers in the 1950s and 1960s but remained largely unknown until the late 1970s. The first formal documents of TPS publicly available were the Toyota’s supplier manuals of 1965 (Holweg, 2007), while TPS became known in the West with the first two papers published in English in the late 1970s (Sugimori *et al.*, 1977; Ashburn, 1977). TPS was formally introduced in the U.S. in 1984 when the New United Motor Manufacturing Company (NUMMI) was established as a joint venture between Toyota and General Motors (Shah and Ward, 2007). At that time, the American production scene was dominated by the use of Material Requirements Planning (MRP I) systems to manage inventories and production (Hopp and Spearman, 2001).

It the early 1980s, TPS attracted wider attention. Western manufacturers, academics, and consultants started visiting Japan to understand the unique Japanese production management practices. Three streams of mutually reinforcing best practices emerged (Schonberger, 2007): the first referred to *employee involvement* practices, the second to *quality* practices also known in Japan as *Total Quality Control* (TQC) and the third to the new *production system* developed by Toyota. TPS soon became synonymous with *Just-in-Time* (JIT) production, a fundamental element of TPS, and started to be considered as the next “big thing” in manufacturing management. Several authors - including Taichi Ohno (1988), a lead engineer at Toyota who is considered the father of TPS, and Shigeo Shingo (1985) who worked with Ohno to develop TPS - revealed philosophical principles, as well as a number of other complementary elements of JIT such as small lot production, setup time reduction, kanban system. These elements are discussed in the following Section.

TQC received significant attention, becoming a movement, known as *Total Quality Management* (TQM), under the influence of American (e.g. E. Deming, J. Juran) and Japanese (e.g. K. Ishikawa) quality pioneers. Thus, in the 1980s the quality movement dominated the performance improvement scene and TQM programs were part of the corporate agenda in every major organization, without necessarily using all JIT elements (Hopp and Spearman, 2001). Concerning JIT, despite its ensuing popularity, implementation results in Western companies were mixed. The lack of a common understanding of what JIT really is, the significant effort, focus and cost to implement it, and the lack of a coherent framework to balance (often) contradicting objectives were some of the reasons that led to limitations in JIT implementations (Hopp and Spearman, 2001). By the mid-1990s the interest on quality and JIT weakened, even though Toyota outperformed its competitors. New movements such as *Business Process Reengineering* (BPR) and *Enterprise Resources Planning* (ERP) were regarded as the next dominant trends.

Nonetheless in 1990, the seminal book *The Machine That Changed the World* (Womack, Jones, and Roos, 1990) introduced *LM* (also known as *Lean Production* or *Lean Management*) and became one of the most widely cited references in operations management over the last decades. The book, a result of the International Motor Vehicle Program (IMVP) of the Massachusetts Institute of Technology (MIT), compared the Western automobile manufacturers to the Japanese ones and showed that the Japanese companies, especially Toyota, were far more efficient. The term *Lean* was introduced by Krafcik (1988) a researcher in the IMVP and MBA student at MIT at that time. Although the concepts and techniques under LM were the same as those of JIT (Hopp and Spearman, 2004; Schonberger, 2007), the book according to its authors made two important contributions: firstly, it extended TPS outside the manufacturing floor and linked it to enterprise processes (such as product development, supplier management, and customer management), and, secondly, it made undeniable that lean practices not only resulted in superior performance, but they were not dependent on culture and hence they could be transferred outside Toyota and Japan (Holweg, 2007). As a result, since the middle 1990s, JIT has become mainstream again under the lean banner, and companies rejuvenated past JIT initiatives, also in industries outside manufacturing (Hopp and Spearman, 2004; Schonberger, 2007).

Following the success of their book, Womack and Jones (1994, 1996) extended the scope of LM and elevated it to a management philosophy, termed *Lean Thinking* (LT). According to the authors, LT goes beyond manufacturing and is not just a set of tools to identify and eliminate waste on the shop-floor, but a philosophy that aims at the creation of value for the customer across and beyond the boundaries of a function or enterprise. The concept of *Lean Enterprise* (LE) was introduced to represent an organization that can transform the value stream across the enterprise for the benefit of the end customer. The concept of LE was further developed by the Lean Advancement Initiative (LAI). Launched in 1993 and active until 2012, LAI was a US-based national consortium between aerospace defense companies, US government, labor unions and academia aiming to transform the aerospace industry under the lean philosophy (MIT-LAI, 2013). In 2002, LAI published *Lean Enterprise Value* (Murman, *et al.*, 2002), which further extended the scope of the LE to an enterprise that can deliver value not just for customers but for all stakeholders (e.g. suppliers, partners, employees, and shareholders). In a recent literature review Stone (2012) reported that the focus in the late 1990s to early 2000s was shifting from implementing lean exclusively on the manufacturing shop floor to other areas of the enterprise such as product development, marketing, sales, service, accounting, and other white-collar functions or processes.

From recent literature reviews on LM (Stone, 2012; Moyano-Fuentes and Sacristán-Díaz, 2012; Jasti and Kodali, 2014; Bhamu and Sangwan, 2014; Jasti and Kodali, 2015a), one may deduce four major trends that emerged in the 2000s and continue to evolve to-date:

- *Merging LM with other approaches* such as Six Sigma and Agile Manufacturing to *Lean Six Sigma* (George, 2002) and *Leagile* (Naylor, Naim, and Berry, 1999). This trend seems to be a return of the above paradigms to their natural environment. For example, Hopp and Spearman (2004) argue that Six Sigma, carries on the legacy of TQM just like LM carries on the legacy of JIT, while Papadopoulou and Ozbayrak (2005) argue that most of the integrated key concepts and tools of agile (e.g. partnerships formation, product and production integration, etc.) are some of the major enablers of leanness.

- *Extension of LM concepts to the service sector and white-collar business functions/ processes*. Womack and Jones (2005a,b) introduced the concept of *Lean Consumption*, to promote LM to the service sector by encouraging companies to deliver better customer experience, more efficiently and with less difficulty and disruption for the customer. Given the increasing importance of services in the economy, they claimed that LM initiatives needed to be better established in order to address the major intrinsic challenges of the service sector. A more detailed review of the evolution of LM in the service sector will be detailed in the following Sections.
- *Extension of LM concepts to the entire enterprise.* Recent studies (Jasti and Kodali, 2015a) indicate that few companies managed to extend lean principles to the areas of product development and other enterprise level functions/ processes. This is common across industries. Still the majority of research and practice is focusing in the area of manufacturing operations instead of across the enterprise.
- *Continuous improvement*. Irrespective the industry, companies that have been successful in initial LM implementations, strive not only to maintain these gains, but to continuously improve and sustain competitiveness. As more challenges and opportunities will emerge from advancements in new technologies and changes in the market place, the role of continuous improvement is becoming more critical.

In the previous paragraphs, we discussed the evolution of LM from TPS and JIT to the LE. In the remaining part of this Section we review the literature defining the elements of LM. Since many of the lean practices discussed below are considered today as commonplace, it is important to discuss first the challenges and historical context under which these practices evolved.

In the middle 1940s, when Toyota started developing its production system, the economy in Japan was suffering in the aftermath of the Second World War. Labor productivity was one-ninth that of that in the United States (Hopp and Spearman, 2001). Toyota's managers realized that due to capital constraints and low volumes in the Japanese market, they could not reduce costs by exploiting economies of scale at a level comparable to that of Ford and GM (Ohno, 1988). Therefore, their manufacturing strategy focused on producing multiple models in small quantities. Hopp and Spearman (2001) argue that from the production point of view the challenge was to maintain a *smooth production flow* while producing a *varied product mix without large* inventories. This seemed impossible at the time given the production practices of their American competitors. However, instead of taking the then assumptions as granted, Toyota's managers recognized that these may change and worked proactively to shape their production environment (Hopp and Spearman, 2001; Pound, Bell, and Spearman, 2014). The system they developed, TPS, rests on two pillars (Ohno, 1988): (1) *Just-in-time production*, or producing what it is needed, when needed, at the quantities needed, and (2) *Autonomation*, or automation with a human touch. Autonomation - an invention borrowed by the automatically activated loom used at Toyoda Spinning and Weaving - refers to *automated* machines that can *detect and signal* abnormal conditions *and stop* automatically if necessary (*fool-proofed* or *poka yoke*). Such machines prevent the production of defective parts and allow operators to intervene only when needed.

JIT production, according to Ohno (1988), involved two components: the *Kanban system* (or *Pull)* and *Level Production*. Pull is a production system that explicitly limits the amount of work in process (WIP) in the system, as opposed to the *push* system where there is no explicit limit on the amount of WIP (Hopp and Spearman, 2001, 2004). Kanban (Japanese word for card) is the mechanism of pull in the form of cards, balls, containers, etc. that is used to authorize the movement or production of parts, and as a result to prevent the accumulation of WIP in the production system beyond a pre-determined limit. Ohno got the inspiration for kandan from the American supermarkets. Just like the customers pull products from the shelves in a supermarket and the empty shelves signal the need to restock them, similarly in a manufacturing setting, the downstream process goes to the upstream one to acquire the needed parts (at the time and quantity needed). The upstream process produces immediately the quantity just taken from its output buffer. However, Ohno and other managers in Toyota realized that JIT and Pull cannot be successful without significant changes in the manufacturing environment. As a result, they introduced a series of suitable interventions as overviewed below.

To establish *Level Production*, they worked internally to integrate marketing, sales and manufacturing to produce a relative stable production schedule and established a *takt time* to set the production output to be equal to customer demand. They also worked with customers to negotiate due dates as well as with fewer suppliers to deliver parts more frequently and at the right quality, at a time when these factors were considered exogenous (Hopp and Spearman, 2001). To accommodate a mixed production schedule (i.e. producing several products at the same production line), *setup* times were drastically reduced in order to reach the target of *one-piece-flow*. This was implemented by simple, general purpose equipment that was modified with simple interventions (Holweg, 2007), as well as through other techniques such as the single-minute exchange of dies (*SMED*) system (Shingo, 1985), uniform product design, parallel processing, etc.

Cross-training for operators and supervisors was also intensively pursued through daily rotation to balance the line, support mix production sequence, etc. In combination with *autonomation*, it became possible for a single operator to work on several machines. To facilitate material flow and avoid unnecessary walking time, the plant layout was also modified, by relocating successive operations next to one another in U-shaped lines (Black and Hunter, 2003), or *cells* (*cellular manufacturing* is discussed more thoroughly in Chapter 5).

Due to the high synchronization between workstations and the low levels of inventory, JIT cannot tolerate defects, scrap, and rework, since these will disrupt production. Therefore, a set of robust quality practices were established to increase visibility of quality issues and identification of their source (i.e. *quality at the source*). These included (Schonberger, 1982, 2007) *statistical methods* (e.g. statistical process control) for controlling quality parameters, *visual management* (e.g. boards, meters, etc.) for easy-to-see quality aspects and immediate feedback to upstream (internal or external) operations, insistence on compliance to *quality standards and standard work methods* (e.g. don’t accept, don’t pass bad quality), *line-stop for nonconformities* with immediate intervention, *correcting one’s own errors* to learn from own failures and avoid them in the future, etc. They also promoted organizational and housekeeping techniques such as *point-of-use system* and *5S*, to remove inefficiencies and organize the production floor.

In order for the above changes to work, operators have to be motivated to take action immediately, solve problems and produce high quality products. A key element of TPS refers to *respect-for-humanity* which, in this particular case, aims to increase the involvement and competence of workforce by providing authority to make process changes, by encouraging suggestions for improvement and by communicating management respect, recognition, and appreciation for the operators (Monden, 1983; Womack *et al.*, 1990; de Treville and Antonakis, 2006).

Finally, a less known aspect of TPS refers to the *management of buffers* also known as *under-capacity scheduling*. In particular, one approach widely used by Toyota to deal with unanticipated disruptions is that of a capacity buffer. By scheduling production into slots of appropriate duration (e.g. 10-2, 10-2, instead of 8-8-8) in order to provide extra (two in this case) hours to provide available time for stopping the line, correcting errors, doing preventive maintenance or catching up with the production schedule if left behind (Pound *et al.*, 2014). In this way, Toyota reduced one buffer (inventory) but made a conscious decision to increase another buffer (capacity) by scheduling a capacity utilization of 83%. As it will be discussed later, this approach is very close to the core of lean. The practices discussed above are detailed in Table A. of Appendix A, along with other practices and tools added by Western researchers and practitioners.

2.2.2 Impact and limits of applicability

In the light of Toyota's success, a considerable number of researchers investigated the impact of LM (we use the terms TPS, JIT, TQM and LM interchangeably) on various aspects of performance. Several studies indicated that LM practices are clearly associated with improved organizational performance (Samson and Terziovski, 1999; Cua, McKone, and Schroeder, 2001; Shah and Ward, 2003; Fullerton, McWatters and Fawson, 2003; Lee and Jo, 2007; Pont, Furlan, and Vinelli, 2008; Furlan, Vinelli, and Dal Pont, 2011) while others reported limited or no effect (Sakakibara, Flynn, Schroeder, and Morris, 1997; Bonavia and Marin, 2006; Arlbjørn and Freytag; 2013).

Due to inconsistencies in the definition of LM, it is difficult to draw aggregated conclusions on the most critical practices. One of the few attempts to extract consolidated results is the work of Mackelprang and Nair (2010). The authors based on an in-depth meta-study of 23 studies spanning from 1992 to 2008, reported a positive relationship between JIT manufacturing practices and aggregate performance.

Another body of research investigated the performance of industrial companies that have adopted LM versus their competitors. The results are mixed. A number of surveys provided evidence that indeed, companies which have adopted LM practices outperform their competitors in terms of operational and financial performance (Chen, Frank, and Wu, 2003; Swamidass, 2007; Demeter and Matyusz, 2011; Hofer, Eroglu, and Rossiter Hofer, 2012). For example, Chen *et al*. (2003) in a study of inventories of publicly traded American manufacturing companies between 1981 and 2000, found that work-in-process inventory, declined by about 6% per year due to LM initiatives. In contrast, Rajagopalan and Malhotra (2001), using data from the US Census Bureau for manufacturing inventories between 1961 and 1994, found that for half of the 20 manufacturing sectors studied, the decrease was larger in the post-1980 period, before LM gained popularity. Schonberger (2007) in a study of inventory turnovers involving more than 1200 companies (including the world's largest, and best-known ones) across 9 regions and 35 industry sectors, reported that in the majority of companies studied inventory turns have not improved, but in many cases have deteriorated over the last 10 years.

Concerning the success rate of LM implementation, a number of empirical case studies reported significant benefits from LM (Moyano-Fuentes and Sacristán-Díaz, 2012; Bhamu and Sangwan, 2014), including cases in industries outside automotive (Billesbach, 1994; de Toni and Tonchia, 1996; Zayko, Broughman, and Hancock, 1997; Hines, Rich, and Esain, 1999; Kumar, *et al.*, 2006; Zokaei and Simons, 2006; Green, Lee, and Kozman, 2010; Issa, 2013; Villarreala, Garza-Reyesb, and Kumarc, 2016). However, despite the above unquestionable success cases, anecdotal evidence suggests that the success of LM implementations is rather low. For example, Hopp (2013) provided three industry sources (Wall Street analyst Cliff Ransom, 2004; Aberdeen Group survey, 2006; Industry week/ Manufacturing Performance Institute Survey, 2007) reporting that among those firms that implement LM only 1-2% have verified financial improvements, less than 20% are best-in-class, and 2% fully achieved their objectives. Spear and Bowen (1999) stated that although many companies applied lean, only few have achieved results with similar success as Toyota. Low success rates have also been reported by other authors (Lucey, Bateman, and Hines, 2005; Anand and Kodali, 2010; Nordin *et al.* 2012). New (2007) in the special issue of the International Journal of Production Research issued to celebrate the first paper in English for TPS (Sugimori, *et al.*, 1977) states: "*the popularity of the TPS as a subject of discussion and research seems only to be matched by the widespread inability of organizations to adopt and apply the ideas with anything like the success of Toyota*".

Finally, another significant stream of literature suggests that despite the respect-for-human rhetoric, LM might cause health and safety issues to the workforce. A number of studies have reported that lean can be "mean" to employee health and safety and can lead to increased injuries, decreased health and possible boredom and stress (Adler, Goldoftas, and Levine, 1997; Landsbergis, Cahill, and Schnall, 1999; Lewchuck, Stewart, and Yates, 2001; Mehri, 2006; de Treville and Antonakis 2006; Conti, Angelis, Cooper, Faragher, and Gill, 2006). In particular, job rotation might cause health and safety issues when performing new activities (Brenner, Fairris, and Ruser 2004). Pressure to improve productivity pushes workers to increase their speed of work which increases the risk of injuries (Kaminski 2001). Standardized processes reduce worker autonomy and freedom almost completely (Treville and Antonakis, 2006).

The above consequences have been debated since a) they can be the outcome of poor management decisions in designing, implementing and operating LM (Parker, 2003; Womack, Armstrong, and Liker, 2009; Hasle, Bojesen, Jensen, and Bramming, 2012), b) LM has been reported to have positive effects on workforce. For example, training may increase workers' health and safety (Kaminski 2001); employee involvement gives workers the opportunity to participate in improvements (Conti *et al.*, 2006); job rotation may have positive effects by reducing boredom from repetitive activities (Womack, Armstrong, and Liker 2009), and, finally, working in teams provides the opportunity for workers to share issues and support each other (Kaminski 2001; Brenner, Fairris, and Ruser 2004; Conti *et al.*, 2006). Unfortunately, these positive aspects of LM have not been observed in all implementations. For example, in one of the latest literature reviews on LM by Jasti and Kodali (2015a), education and training did not get a place in the top 25 LM elements, clearly showing that most organizations have not considered training critical in their LM transformation. In any case, we may argue that if LM is not implemented properly it can produce negative effects to the workforce. As a consequence, the related issues need to be identified and addressed. De Treville and Antonakis (2006) suggest an approach to do so, which will be discussed in the next Section.

From the above we can conclude that while LM has shown significant success, at the same time it may also prove to be problematic. As Hopp (2013) argues, "*a fair assessment is that lean can produce spectacular results, but this is rare*". We summarize the potential causes in the following three groups:

The first refers to the *technical limitations* in applying lean. This includes a wide range of factors ranging from selecting the right scope to address tough issues requiring inter-company collaborations (Schonberger, 2007), to managing the financial implications of a LM transformation (Cooper and Maskell, 2008), or extending LM in non-repetitive manufacturing environments. Especially for the latter topic, LM was not considered applicable in continuous processes or in discrete but non-repetitive process sectors (e.g. job-shops). The former is characterized by very high volumes, low variety, inflexible processes that are uninterruptable and intrinsically efficient (Abdulmalek, Rajgopal, and Needy, 2006; Abdulmalek and Rajgopal, 2007). Job shops are characterized by high demand variability and product customization which limits production levelling (Jina, Bhattacharya, and Walton, 1997). For these environments, it has been suggested that LM can be applied in non-production activities or in areas with work-in-progress inventory (Abdulmalek and Rajgopal, 2007), or to the most frequent demanded products (i.e. runners) of a job-shop (Jina, Bhattacharya, and Walton, 1997). A few cases exist, in which LM control principles, such as levelling, pull and takt time have been applied to a job-shop environment (Slomp, Bokhorst, and Germs, 2009), while other cases suggest that instead of trying to implement TPS tools such as kanban, heijunka, etc., the idea is to design a comprehensive system that satisfies the guiding principles of TPS and either use the tools as they are, modify them, or change them completely to fit the needs of the organization (Lander and Liker, 2007).

The second refers to the *soft challenges* typically stemming from the change management and transformation aspects of a LM implementation. These have been also known as critical success factors (CSFs). According to Boynton and Zmud (1984), CSFs are "*those few things that must go well to ensure success for a manager or an organization, and, therefore, they represent those managerial or enterprise areas that must be given special and continual attention to bring about high performance*". From the numerous attempts to define the CSFs over the past years from areas such as Lean, TQM, JIT, Six Sigma (for a comprehensive list see Netland, 2016), it seems that the three most important CSFs are *management commitment and involvement, training and education,* and *employee participation and empowerment*. An interesting extension of this stream of literature investigates whether generic CSFs need to be differentiated and tailored according to the needs of the different environments that implement LM (Sousa and Voss, 2001). We will discuss further the implications on services in the next Sections.

Although the above two causes provided invaluable insights to the LM body of knowledge, it has been argued that, to a large extent, both stem from the difficulties in *understanding the true essence of lean* (Hopp, 2013). It seems that there was a lot of freedom to interpret LM from the original writings of Ohno that eventually led to confusion and misconceptions about what LM really means (Papadopoulou and Ozbayrak, 2005; Shah and Ward, 2007; Hopp and Spearman, 2001, 2004; Hopp, 2013). Probably the most known example is the confusion around pull and push. Hopp and Spearman argued that "*the book Lean Thinking was just one of the many books and articles that confused the concept of pull with the simpler idea of make-to-order. This led managers to believe that pull is make-to-order, while push is make-to-stock. However, pull can be make-to-stock, or even make-to-forecast. As a result, many practitioners have found the literature on lean confusing and difficult to implement*". (For a complete discussion see Hopp and Spearman, 2004).

This confusion has led to confusion regarding other topics, including the definition, elements and the true essence of lean. For example, Bhamu and Sangwan (2014) listed 33 different definitions of LM from various authors most of which centered around waste and cost reduction. Selected definitions are presented in Table 2.1.

Table 2.1: Lean manufacturing definitions

Author(s)	Description
Womack and Jones (1996)	Lean thinking is a business methodology that aims to provide a new way to think about how to organize human activities to deliver more benefits to society and value to individuals while eliminating waste
Liker (1996)	A philosophy that reduces the time from customer order to delivery by eliminating sources of waste in the production flow
Shah and Ward (2003)	Lean Manufacturing can be best defined as an approach to deliver the upmost value to the customer by eliminating waste through process and human design elements
Hopp and Spearman (2004)	Production of goods or services is Lean if it is accomplished with minimal buffering costs
May (2005)	Lean for knowledge work is the creation of value through flow of information (the primary basis of value in knowledge work) to the right person, in the right form, at the right time, at the lowest cost with the highest quality possible
De Treville and Antonakis (2006)	Integrated manufacturing system intended to maximize capacity utilization and minimize buffer inventories through minimizing system variability
Shah and Ward (2007)	An integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability
Holweg (2007)	Lean Manufacturing can be interpreted as a managerial philosophy and a set of integrated socio-technical practices aimed at eliminating waste along the whole value chain within and across companies
Radnor (2010)	A management practice based on the philosophy of continuously improving processes by either increasing customer value or reducing non-value adding activities (Muda), process variation (Mura), and poor work conditions (Muri)

Note: Adapted from Bhamu and Sangwan (2014) and Gupta *et al.* (2016)

Other authors tried to capture the essence of LM by decomposing it either in a set of tools and practices (see for example, Shah and Ward, 2003) or in a set of principles. For example, Womack and Jones (1996) defined five principles, Spear and Bowen (1999) four, Liker (2004) fourteen, and so on. The most cited *lean principles* are presented in Table 2.2. These cover a wide spectrum of manufacturing areas, including production (Womack and Jones, 1996; Spear and Bowen, 1999), management (Liker, 2004), and product development (Liker and Morgan, 2006). These principles are usually manifested in a number of practices and tools. However, most authors agree that lean is not just a set of tools, but a philosophy and culture towards customer and employee centricity, waste reduction, and continuous improvement.

Table 2.2: Lean manufacturing principles

Area	Principle	Description	Source(s)*
Lean Production - Generic	Specify value	Define value precisely from the perspective of the end customer in terms of a specific product with specific capabilities offered at a specific price and time	(1)

Area	Principle	Description	Source(s)*
	Identify the value stream	Identify the entire value stream for each product or product family and eliminate waste	(1)
	Flow	Make the remaining value creating steps flow. Making steps flow means working on each design, order, and product continuously from beginning to end so that there is no waiting, downtime, or scrap within or between steps	(1)
	Pull	The end customer pulls the product from the value stream in a fashion that eliminates muda in the form of designs that are obsolete before the product can be introduced, finished-goods inventories, and remaindered goods no one wants	(1)
	Perfection	Pursue perfection as there is no end to the process of reducing effort, time, space, cost, and mistakes while offering a product that is ever more nearly what the customer actually wants	(1)
Lean Production - Design	Standardized work	All work shall be highly specified as to content, sequence, timing and outcome	(2)
	Direct customer-supplier connection	Every customer-supplier connection must be direct, and there must be an unambiguous yes-or-no way to send requests and receive responses	(2)
	Simple and direct product and service pathways	The pathway for any every product and service must be simple and direct	(2)
	Improvements using the scientific method	Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization	(2)
Lean Management - Long-term philosophy	Base your management decisions on a long-term philosophy even at the expense of short-term financial goals	Build a philosophical sense of purpose that supersedes any short-term decision making and align the organization towards this common purpose	(3)
Lean Management - The right process will produce the right results	Create a continuous process flow to bring problems to the surface	Redesign work processes to achieve high value-added, continuous flow	(3)
	Use “pull” systems to avoid overproduction	Provide what customers want, when they want it and, in the amount, wanted. Be responsive to shifts in demand changes	(3)
	Level out the workload (work like the tortoise, not the hare)	Work to level out the workload and eliminate overburden to people and equipment by eliminating unevenness in the production schedule	(3)
	Build a culture of stopping to fix problems, to get quality right the first time	Build into the equipment the capability of detecting problems, stopping itself and alert. Build into culture and in systems the philosophy of doing it right the first time and quickly solve problems	(3)
	Standardized tasks and processes are the foundation for continuous improvement and employee empowerment	Use stable, repeatable methods to maintain predictability, time and quality. Capture the accumulated learning about a process up to a point by standardize best practices and have a process to do it repeatedly	(3)
	Use visual control so no problems are hidden	Use simple visual indicators to detect deviations	(3)
	Use only reliable, thoroughly tested technology that serves	Use technology to support and not replace people. Conduct actual tests before adopting new technology and implement it if it has proven in trials and it can improve flow	(3)

Area	Principle	Description	Source(s)*
	your people and process		
Lean Management - Add Value to the Organization by developing your People and Partners	Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others	Grow leaders from within and have them be role models of the company's philosophy and way of doing business. A great leader must understand the daily work in detail so he or she can be the best teacher	(3)
	Develop exceptional people and teams who follow your company's philosophy	Create a strong culture in which company values and beliefs are widely shared and lived over time. Empower people to work in team towards common goals	(3)
	Respect your extended network of partners and suppliers by challenging them and helping them improve	Respect partners and suppliers and treat them as extensions of your business. Challenge them and set challenging targets and assist them in achieving them	(3)
Lean Management - Continuously solving root problems drives organizational learning	Go and see for yourself to thoroughly understand the situation	Solve problems and improve processes by going to the source and personally observing and verifying data at all levels in the organization	(3)
	Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly	Do not pick a single direction but keep alternatives open. Discuss problems and solutions with all those affected, to collect ideas and get agreement on the path forward. Once chosen they are implemented rapidly	(3)
	Become a learning organization through relentless reflection and continuous improvement	Once stable processes are established continue to seek improvements. Protect organization knowledge by developing stable personnel, slow promotion, and very careful succession systems	(3)
Lean Product Development - Process	Establish customer-defined value to separate value added from waste	Lean is a never-ending journey of waste elimination. Waste is non-value added defined by first defining customer value	(4)
	Front load the product development process to thoroughly explore alternative Solutions while there is Maximum Design Space	Defining the wrong problem or premature convergence on the wrong solution will have costs throughout the product life cycle. Taking time to thoroughly explore alternatives and solve anticipated problems at the root cause has exponential benefits	(4)
	Create a leveled Product Development Process Flow	Leveling the flow starts with stabilizing the process so it can be predicted and appropriately planned. This allows product planning to reduce wild swings in work load. Predictable work load swings can be staffed through flexible labor pools	(4)
	Utilize Rigorous Standardization to Reduce Variation, and Create Flexibility and Predictable Outcomes	Standardization is the basis for continuous improvement. Standardization of the product and process is a foundation for all the other process principles	(4)
Lean Product Development - People	Develop a "Chief Engineer System" to Integrate Development from start to finish	The chief engineer is the master architect with final authority and responsibility for the entire product development process. The chief engineer is the overarching source of product and process integration	(4)
	Organize to balance Functional Expertise and Cross-functional Integration	Deep functional expertise combined with superordinate goals and the chief engineer system provides the balance sought by matrix organization	(4)

Area	Principle	Description	Source(s)*
Lean Product Development - Tools and Technology	Develop Towering Technical Competence in all Engineers.	Engineers must have deep specialized knowledge of the product and process that comes from direct experience at the Gemba	(4)
	Fully Integrate Suppliers into the Product Development System	Suppliers of components must be seamlessly integrated into the development process with compatible capabilities and culture	(4)
	Build in Learning and Continuous Improvement	Organizational learning is a necessary condition for continuous improvement and builds on all of the other principles	(4)
	Build a Culture to Support Excellence and Relentless Improvement	Excellence and kaizen in the final analysis reflect the organizational culture.	(4)
	Adapt Technology to Fit your People and Process	Technology must be customized and always subordinated to the people and process	(4)
	Align your Organization through Simple, Visual Communication	Aligned goals must be cascaded down and joint problem solving is enabled by simple, visual communication	(4)
	Use Powerful Tools for Standardization and Organizational Learning	Powerful tools can be simple. Their power comes from enabling standardization which is necessary for organizational learning	(4)

* Sources: (1) Womack and Jones (1996), (2) Spear and Bowen (1999), (3) Liker (2004), (4) Liker and Morgan (2006)

The above work has been the subject of criticism since a) the idea of waste reduction is not something new, b) TPS was a collection of techniques, beliefs and practices that Toyota managers evolved over the years to address specific challenges and not any short of quick-fix panacea for every environment, c) existing definitions do not provide a coherent framework to balance (often) contradicting objectives. We therefore selected the work of Hopp and Spearman (2001, 2004), de Treville and Antonakis (2006), and Hopp (2013) to form the base model to explain the revolutionary aspects and essence of lean, which is presented in the next Section.

2.2.3 Revolutionary aspects and essence of lean manufacturing

Looking at the historical evolution of TPS and its practices (for a comprehensive review see Schonberger, 2007 and Shah and Ward, 2003, 2007), we can conclude that a lot of these practices were not originated in Toyota. New (2007) argues that: "*Toyota's managers are rightly proud of its achievements, and the official story naturally centres on the creativity and ingenuity of Toyota managers, but it would be a mistake to think that the firm has not benefited from learning from constant cross-fertilization from the experiences and innovations of Honda, Kawasaki, Nissan and others, and the teachings of Deming and Juran*".

Indeed, the moving assembly line was borrowed from Ford, the Kanban system inspired from the American supermarket, the automated fool-proofed machines from the Toyoda Spinning and Weaving and the Cable Car System in San Francisco (Black and Hunter, 2003), quality techniques from the American Quality pioneers, continuous improvement from the

Training within Industry (TWI) program (Huntzinger, 2002), the takt time concept from the Focke-Wulff aircraft company in Germany (Holweg, 2007), total preventive maintenance from Nippondenso in 1969 (Schonberger, 2007), and so on. Given the above, then one might wonder what made the approach so revolutionary. Hopp and Spearman (2001, pp. 165) summarized the key insights that according to their view made TPS to deserve a prominent place in the history of manufacturing management:

- *Technological advancements*. The simple and flexible equipment purchased by Kiichiro Toyoda in the 1930s (Holweg, 2007), the autonomation of machines developed by Ohno (Ohno, 1988), as well as the level of factory automation (Coffey, 2006), although didn't receive much attention from the wider public (Hopp, 2013), enabled many of the concepts essential to TPS, especially setup reduction and quality of output.
- *Holistic approach*. Toyota's managers followed a holistic, systems approach that focused on aligning different functions and their interfaces towards the achievement of the overall goals of the system. For example, the cross-functional focused work cells (plants-in-a-plant), broke down the functional silo system and acted as somewhat like small companies (Schonberger, 2007).
- *Reshape of the production environment*. As already mentioned, Toyota's managers challenged the production environment and worked proactively to shape it. This innovative aspect of TPS includes revolutionary practices such as the reduction of setups, the manufacturability of product designs, and the alignment of commercial and manufacturing practices to achieve stable production plans that improved significantly the overall effectiveness of the system.
- *Focus on operational details*. In contrast to the concept of the *fast-track* manager, Toyota's managers had deep knowledge of every detail of their business similarly with old industrialists such as Andrew Carnegie and Henry Ford. Realizing that operational details mater strategically, they were willing to examine every detail of their manufacturing process to reduce waste.
- *Importance of controlling WIP*. Famous practices such as pull production and kanban was the result of the realization that lowering and controlling WIP levels benefits the overall production system. In fact, all benefits of JIT come from lower levels of WIP either because it shortens cycle time or because it creates pressure to keep high quality levels and reduces the associated costs of maintaining in-process inventory.

- *Importance of pursuing Flexibility*. A lean environment is inherently inflexible since it is based on high process standardization and requires demand stability for the cellular structures to operate smoothly (detailed in Chapter 5). To cope with this inflexibility as well as with market changes, Toyota's managers institutionalized practices that promote flexibility such as short setup times, capacity buffers, cross-training, and other.
- *Priority on Quality versus Throughput*. Although quality concepts originated in the U.S., the Japanese embraced them and integrated them in their culture and production system far more successfully than their American competitors. In this way, Hopp and Spearman (2001) state: "*they demonstrated that a system in which quality takes precedence over throughput and is assured at the source not only works but it is profitable as well*".
- *Necessity of Continuous improvement*. The Japanese realized that continuous improvement of the production environment in the light of volatile and continuous changing markets, was a condition for survival. They achieved it through persistent root cause problem solving (e.g. Ohno used to ask *why 5 times* to identify and remove obstacles to the primary objective) and incremental changes (e.g. it took Toyota approximately 25 years to perfect TPS).

Finally, to define the essence of LM we return to the original writings of Ohno. According to Ohno (1988), performance deteriorates due to three obstacles or inefficiencies (in Japanese): *mura*, i.e. variability or inconsistencies, or anything in a system irregular or unpredictable, *muri*, i.e. excessiveness, overburden or stress of people (or equipment) leading to unmotivated people and potentially to absenteeism and attrition (or downtime and cost to repair or replace the equipment), and *muda*, i.e. waste or activities that consume resources but add no value to the end product. Muda is considered to be waste, while mura and muri are considered to be sources of waste, that is conditions that lead to the creation of waste (Thürer, Tomasevic, and Stevenson, 2016). Ohno further described seven types of wastes that should be eliminated in order to improve performance (see Table 2.3, muda in 3rd column). The list was enhanced later by Womack and Jones (1996) with the addition of an eighth waste, the unutilized skills of employees.

Despite the popularity of these eight wastes, Hopp (2013) argue that the list is incomplete (e.g. does not include waste of unutilized capacity or natural resources and space) and inconsistent (e.g. overproduction is a cause, while inventory a consequence) leading often to unproductive discussions as to how to classify wastes. He further suggested that irrespective the taxonomy, any system will produce only three wastes, inventory, time and capacity and matched Ohno's seven wastes to this definition (see Table 2.3, muda in 2nd column). According to Hopp's rational, wastes can be classified in *coordination* and *execution*. The former is the result of lack of coordination between orders, inputs, resources and outputs, while the latter concerns less the interfaces and more the efficiency of individual processes. Both types of waste consume inventory, capacity and or time and can influence each other, i.e. execution waste (e.g. rework) would delay a production system even if all other activities were perfectly coordinated. Typically, the execution waste is the most obvious waste, and the easiest to eliminate, e.g. extensive setups, rework for known reasons, etc. Hopp and Spearman (2001) state: "*unfortunately, this tends to be the focus and limit of most lean implementations that never get to the real "meat" of the problem*". Indeed, according to Jasti and Kodali (2014), value stream mapping (tool for waste elimination) is the most frequent LM element used in academic papers.

Table 2.3: Types of inefficiencies and their sources (Original synthesis and enhancement by the author from key works of Hackman and Oldham, 1976; Ohno, 1988; Hopp and Spearman, 2004; de Treville and Antonakis, 2006; Hopp, 2013)

Inefficiency	Source	Types (indicative)
Mura, i.e. variability or inconsistencies	External, i.e. variability caused by external factors, often the consequence of a firm's business strategy	*Product variety inconsistent with strategy or not generating sufficient revenue to justify its cost i.e.* offering high levels of product variety, pushing or interrupting operations to "make the numbers" or satisfy unique customer requests
		Demand variety, i.e. fluctuations predicted or unpredicted in demand over a period
		Supply variability, i.e. delivery times, number and types of sources, quality of input, etc.
	Internal i.e. variability caused by internal factors, often the consequence of a firm's operations strategy and practices	*Equipment variability*, i.e. setups, downtime (scheduled and unscheduled), yield loss, etc.
		Operators variability, i.e. staffing levels, process time, yield loss, etc.
		Systems and process variability, i.e. product and process design options, layout, structure, methods to prioritize and balance load etc.
Muri, i.e. excessiveness, overburden	*Overused machines and equipment*, i.e. machines outages, wearing or getting obsolete	*Maintenance* and *workload control policies*, i.e. to prevent improper usage for extended time periods (linked with equipment variability above)
	Overworked workforce (i.e. overburdened or stressed workforce for extended time periods)	*Capacity planning* and *workload control policies*, i.e. to prevent people from overwork and ensure time for continuous improvement (linked with operators' variability above)
	Unmotivated workforce (i.e. low motivation and gratification for the work typically the result of work design). Both results typically in lower productivity,	*Meaningfulness*, i.e. the extent to which workers experience meaningfulness in their work. This is determined by: a) *Task significance*, i.e. ability to have a positive impact on other people, b) *Task identity*, i.e. opportunity to complete work in its

Inefficiency	Source	Types (indicative)
	higher overtime, and eventually absenteeism and turnover	entirety, and c) *Skill variety*, i.e. chance of using a range of capabilities
		Responsibility, i.e. the extent to which workers have responsibility in their work. This is determined by *Autonomy*, i.e. discretion on how and when to do the work
		Feedback, i.e. clear and direct information on performance, i.e. the knowledge workers have of the results of their work
Muda, i.e. waste or non-value-added tasks: *Coordination (less obvious, hidden) waste*	*Inventory waste* i.e. inputs that are not immediately used by the process and outputs that are not immediately delivered to the customer. Applies to all materials been idle and the associated costs of maintaining them	*Inventory*, i.e. any inventory above the level that maximizes profit, cash flow and other strategic considerations (to buffer against variability in supply, processing time, and demand) is considered excess
	Time waste, i.e. any delay predicted or unpredicted in delivering a good or service	*Waiting*, i.e. the potential loss from not delivering promptly to the customer and any associated costs
	Capacity waste (unutilized), i.e. capacity not been used, sitting idle	*Lost capacity* and the associated costs from resources (machines, people) that are being idle. Typically, the capacity level is determined by the one which optimally balances the cost of over with under capacity
Execution (obvious) waste	*Capacity waste (not properly used)*, i.e. busy resources but not used in an appropriate or effective way	*Overproduction*, i.e. producing more or before needed (e.g. excess inventory) or without being asked (e.g. undesired features of products/ services) – Relates also with the lost capacity and associated costs for building unwanted features
		Over-processing, i.e. over engineering things or adding complexity not required
		Transportation, i.e. moving of resources (e.g. materials) not actually required to perform the processing
		Unnecessary motion, i.e. ergonomic motions related to people and layout more than required or inappropriate to perform the processing
		Defects, i.e. the effort involved in inspecting for and fixing defects, or the cost of products being scraped
		Non-utilized skills, i.e. non-utilizing people or machine capacity

However, the less obvious (but more pronounced) waste in most production systems, is the coordination waste which is driven by *mura* or variability. The sources of variability can be internal or external (Table 2.3, mura, in 2nd, 3rd columns), but not all types of variability are adverse. Sometimes variability is justified by strategic objectives (e.g. adding product variety to compete in a new segment), but in other times it is not (e.g. disrupting operations to satisfy the needs of one client). According to Pound *et al.* (2014) variability is undesirable only if it reduces a desired combination of profit, cash flow and service. In particular, they argue that if the cost to reduce variation is greater than the revenue generated by the increased benefits (e.g. speed of delivery), then reducing variation will be adverse.

In any case, Hopp and Spearman (2004) argue that since there is always variability in a system, it will be buffered by a combination of inventory, capacity and or time. These buffers are known as *variability buffers* (since they are caused by variability). According to Hopp and Spearman (2001) "*a buffer is an excess resource that corrects for misaligned demand and transformation*". Furthermore, all buffers cost money (inventory and capacity cost money, while time is a loss of value for the customer and hence a potential loss to the producer). Hence, the first objective of lean is to remove the *obvious, execution* waste, the second objective is to remove the *undesirable variability* that increases buffers, while the third objective (given that buffers have different costs) is to find the *right mix of buffers* to address the remaining variability. This is what Toyota actually did, with practices such as demand smoothing, setup reduction, quality at source, etc. they tried to remove variability, while the decision to operate with low inventories (inventory buffer) and higher capacity (capacity buffer) to accommodate disruptions, was because capacity was less expensive than inventory. Therefore, Hopp and Spearman (2004) provide the definition of lean: "*Production of goods or services is lean if it is accomplished with minimal buffering costs*". In their seminal book *Factory Physics*, Hopp and Spearman derived a set of axiomatic mathematical laws (relationships) that govern the sizes of buffers (capacity, inventory and time) and the various types of variability.

Ohno's third inefficiency, *muri*, refers to situations, in which employees get overburden or stressed due to the high workload (over an extended period), or due to general conditions in their work (overburden relates also to machines and equipment). As a consequence, they might lose opportunities to perform creative aspects in relation to their job (e.g. problem solving and improvement initiatives), hence lose interest, and feel demotivated or at worse get injured or burned out. As mentioned earlier, this is a typical situation of LM initiatives gone badly, i.e. capacity buffers were reduced aggressively (with no other changes) restricting any effort in the organization for continuous improvement. De Treville and Antonakis (2006) and Hopp (2013) argue that the respect-for-human element can be realized in the context of a LM transformation using the Job Characteristics Model (JCM), the most generally accepted theory of job-design motivation (originally proposed by Hackman and Oldham, 1976).

According to the JCM, objective changes to a given job are expected to, in turn, change how the worker perceives the job along five core job dimensions: skill variety, task identity, task significance, autonomy, and feedback (Table 2.3, muri, in 2nd, 3rd columns). Hopp (2013) argues that by respecting the diversity in individual preferences (e.g. not all workers regard problem solving as a positive addition in their duties), JCM can make the job more interesting for workers (thereby reducing boredom) and maximize the use of worker knowledge and skills (thereby increasing resource utilization and opportunities for improvements from within). He also provided various examples of organizations that made changes to each dimension of the JCM and defined as *Positive Lean* “*an aspirational situation in which efficiency improvements actually increase worker motivation, which in turn drives further efficiency improvements*”.

We mentioned earlier the confused landscape around the definition and objectives of lean. Pound *et al.* (2014) suggest that although the focus on implementing TPS and eliminating waste can produce initially substantial results, is a means to an end and not the end itself which is *long-term profitability*. Similarly, reduction of variability at the lowest possible level may not be always the best strategy as it might produce detrimental results (as it was the case with Ford and the Model – T, i.e. “*any color the customer wants as long as it is black*”).

We summarize this background review with the objective of LM and the elements that, in addition to the revolutionary aspects of TPS described above, constitute its essence: the objective of LM is *long term profitability* according to the company’s strategy; this is achieved with *minimization of waste and undesirable variability*, *minimal buffering costs* (or at the level that *maximize profits and cash flow*) and a *self-motivated workforce* to drive continuous improvements.

2.3 Applicability of lean manufacturing concepts to services

In the previous Section we reviewed the history and evolution of LM and described key concepts and components. The current Section focuses on the core of this dissertation and investigates the applicability of LM in services, i.e. the relevance of LM concepts to the challenges faced by service organizations from the theoretical standpoint. In particular, first we review the *evolution of LM in services* along with important *theoretical and conceptual* contributions in the field. Subsequently, we clarify *what* constitutes LS in terms of definitions, principles and frameworks, as well as the types of wastes found in services. Finally, we examine *limitations and extensions of LM concepts* in services.

2.3.1 Evolution of lean manufacturing in services

Transferring industrial concepts to service environments is not a new practice. According to the chronology of *big ideas* across service industries compiled by Chase and Apte (2007) and overviewed in Table 2.4, industrial concepts have influenced the literature on service operations for almost a century (1900-90s). According to the authors, early applications of scientific management in services in the 1920s-40s included examples related to operating room operations in healthcare (e.g. arranging instruments and supplies to facilitate the work of surgeons and nurses) and to mail-order houses (e.g. shorting mails based on complexity and assigning *standard* and *difficult* cases to different groups). Two early well-known examples of companies that used industrial concepts include *Disney* and the *Holiday Inn* hotel chain. Both cases set basic principles in service operations; the former for managing *customer's total experience* and the latter for *maintaining consistent quality* in each of its hotels nationwide. The industrial concept transferred in both cases was related to standardization of operations. For example, in Disneyland, theme parks were carefully designed, staffed with highly trained employees dressed as famous Disney characters who followed rigid scripts in their interactions with customers (Chase and Apte, 2007).

Table 2.4: History of research in service operations: big ideas (Chase and Apte, 2007)

Time period	Big ideas: theory and practice
1900-1950s	Application of scientific management to services Walt Disney: industrialized fantasy Holiday Inn: consistency in multi-site services
1960s	McDonald's: production-line approach to services Service economy and operations in health care
1970s	Industrialization of services Match supply and demand in services The customer contact model Data envelopment analysis
1980s	Classify services to gain marketing and operational insights Gap model of service quality and SERVQUAL Strategic service vision Unconditional service guarantee Psychology of queues
1990s	Service-Profit chain Using poka-yoke, or fail-safe, methods to prevent human errors Globalization of information intensive services Emergence of experience economy
2000s	Using behavioral science in service operations Managing operations in information intensive services Information technology in services and e-services Global business process outsourcing Service design

Probably the most cited example of an industrialized service is related to the restaurant fast-food chain McDonald's, as described in Levitt's seminal paper *Production-line approach to service* (Levitt, 1972). Levitt argued that service companies could increase their efficiency, lower cost and satisfy customers by adopting production methods from manufacturing (Levitt, 1972, 1976). The main characteristics of the production-line approach include (Bowen and Youndahl, 1998; Chase and Apte, 2007):

- *Service standardization*, i.e. a limited offering such as a standard menu to reduce product variety and ensure process control and uniform quality;

- *Division of labor* i.e. work broken down into routine, highly standardized tasks, allowing limited span of control and minimum skills and training time for employees;
- *Limited discretion*, i.e. employees performing well defined tasks requiring limited discretion to ensure uniform quality;
- *Technology substituting people*, i.e. systematic use of equipment and technology to replace labor and scale up service operations at acceptable cost and quality levels;
- *Close performance management*, i.e. managers monitoring the performance of processes and employee activities.

Other examples of industrial concepts applied in services in the 1980s are related to *operational aspects of health care*, such as layout, location and capacity problems (Chase and Apte, 2007), and the decoupling of services into *front-office and back-office* operations, with the latter run like factories potentially in low cost locations (Chase, 1981).

However, in the 1990s the appropriateness of production-like approaches transferred from manufacturing to services was challenged by several authors. To some extent, this can be attributed to the quality revolution of the 1980s that placed customers and employees at the center of operations (Suárez-Barraza, Smith, and Dahlgaard-Park, 2012). For example, according to Schlesinger and Heskett (1991a, b), the production-line approach, while efficient, does not respond well to the varying needs of customers and employees creating a vicious cycle also known as the *cycle of failure* (discussed in detail in Chapter 4). According to this concept, the industrialization of a service creates an inherent inflexibility (due to the limited service offerings and the rigid, technology-driven production system) that degrades quality of service and leads to dissatisfied customers and employees, more customer churn and employee turnover, and eventually lower productivity and profits. Heskett *et al.* (1994) evolved the previous concept into a new one, the *service-profit chain*, suggesting that a company's profitability and revenue growth are determined by the satisfaction and loyalty of its employees. The authors further illustrated companies (such as *Taco Bell* and *Southwest Airlines*) and their related policies that place service and customer-facing employees at the center of their strategy. These policies include:

- *Elimination of low value-added* activities or transferring those to back office

- *Empowerment of employees* for on-the-spot problem solving, through the necessary job enhancements, appropriate selection and training, compensation for performance, etc.
- *Technology that supports* and not just monitors or replaces employees
- *Fewer layers* of management, where managers *coach and support* rather than direct and control

In the 1990s, and after a decade since the JIT concept had been introduced in manufacturing, several authors suggested its application in various service operations. For example, Billesbach and Schniederjans (1989) provided an example of a successful application of JIT in administrative processes. Mehra and Inman (1990) suggested a JIT implementation in a packed goods company. Wasco, Stonehocker, and Feldman (1991) presented a JIT implementation in the Quality Assurance department of a printing company. Other authors presented examples of specific JIT concepts applied in the service sector. Chase and Stewart (1994) suggested the application of *poka-yoke* methods to prevent human errors in service delivery. Duclos, Siha, and Lummus (1995) presented JIT examples for airlines, insurance, retailers and mail-order firms as well as for support functions associated with manufacturing firms, such as purchasing, maintenance, order entry and invoicing.

Despite local successes, the two service sectors that benefited mostly from JIT concepts is retail and healthcare (for medical supplies), where inventories play a major role in operations. For example, *Wal-Mart* was one of the first retailers to apply the pull concept (Schonberger, 2007), by providing daily sales data directly to selected manufacturers, who in turn managed the retailer's inventories in a continuous replenishment mode (a.k.a. vendor-managed inventory or, in groceries, efficient consumer response). *Dell*, *K-mart*, *UPS* and *Mayo Clinic* used JIT techniques to reduce significantly inventories and the associated cost (Yasin *et al.*, 2003; Schonberger, 2007). However, although papers regarding JIT in services continue to be published in the 2000s (see for example Canel, Rosen, and Anderson, 2000; Yasin, Small, and Wafa, 2003; Krishnamurthy, 2007), it seems that JIT did not gain similar popularity across many other service sectors.

Nevertheless, the substantial popularity of LM in the early 1990s reignited the interest for industrial concepts in services, although with a noticeable delay. In the middle 1990s, as already mentioned, Womack and Jones (1994, 1996) suggested that LM can be applied to any process, irrespective the function or industry. The explicit term LS was introduced in the academic literature by Bowen and Youndahl (1998). In their seminal paper *"Lean" service: in* *defense of a production-line approach*, the authors defended the transfer of manufacturing concepts to service operations, in contrast to the criticism at the time. They argued that service businesses should not abandon production-line thinking but shift the rigid production-line approach to a new lean paradigm that favors flexibility and customization, in direct similarity to manufacturing operations. Based on the previous work of Schlesinger and Heskett (1991a, b) and Heskett *et al.* (1994), and using examples from successful service companies such as *Taco Bell*, *Southwest Airlines* and *Shouldice Hospital*, they defined the characteristics of LS. This constitutes the first theoretical framework of LS (discussed below).

Following Bowen and Youndahl's seminal paper on LS, several related papers were published in the 2000s and onwards. Gupta, Sharma, and Sunder (2016), in their latest literature review on lean services, indicate that the interest on the topic peaked between 2010 to 2013 with twenty-four papers in 2011. The authors also concluded that it took almost two decades for lean to gain momentum in services since the introduction of the concept in the 1990s in manufacturing. Furthermore, the majority of published papers, at least prior to 2008, focused on concepts, indicating early efforts to explore and clarify lean in services. For example, from the papers reviewed by Suárez-Barraza *et al.* (2012) more than 50% were conceptual, while from those reviewed in Gupta *et al.* (2016) almost 40% fell into this category.

We present below the conceptual contributions to LS from past research classified into *two streams*: the essence of lean and wastes found in services and finally the limitations and extensions of lean in services.

2.3.2 The essence of lean services

Many service researchers attempted to define the *essence of LS* using *definitions*, *principles*, and *frameworks*, most of them already proposed in the manufacturing literature.

In terms of *definitions*, LS is described through activities focusing on *value creation* and *waste reduction*. The corresponding *concepts* adopted from the manufacturing literature include the concepts of *value-adding activities* by Womack and Jones (1996) and that of the *seven wastes* from T. Ohno (1988) (discussed in the next Section). According to the former, all work activities can be classified in:

- *value adding*,
- *non (or low) -value adding that cannot be eliminated* (e.g. for regulatory reasons) and

- *non-value adding that can be eliminated* (i.e. waste).

Value (or waste) is defined as: a) something that the customer is (not) willing to pay for i.e. *(not) doing the right thing*, which relates to (un)desired product or service features, or b) any human activity which absorbs resources and creates (no) value to the end product or service, i.e. *(not) doing things right*, which relates to the efficiency of the resources used.

These concepts, however, have also been subject to criticism. According to Pound and Spearman (2007), the *value-adding* classification is highly subjective; customers perceive value differently, while typically they do not care on a company's internal processes, provided they are legal. It can also be demotivating for skilled professionals to classify their work as necessary non-value add (e.g. inspection professionals). Most importantly, a strict focus on eliminating waste is not the best way to improve performance and profitability. In our view this classification makes sense only for *product or service features* and not for processes, unless these processes are performed by customers.

Besides the *value and waste* concepts described above, we distinguish two important contributions in defining the essence of LS.

The first is from Seddon (Seddon, 2005; Seddon and Caulkin, 2007; Seddon *et al.*, 2011). The author, influenced by the American quality pioneer Edward Deming, argued that superior performance in services comes when service managers adopt a *holistic-systemic* view on the way service systems are designed and managed. He stated: "*while Ohno's (TPS) purpose was to build cars at the rate and variety of demand, a transactional service system's purpose is to absorb the variety of customer demand*". Given that customers perceive value differently, service organizations need to be capable in understanding those needs and addressing them at the first point of contact (*service encounter*). Multiple inefficiencies found in service environments (such as *failure demand*, i.e. demand created as a result of failures) can be attributed to concepts and tools transferred from manufacturing without understanding clearly the problems to be addressed and the related causes in services. Seddon argues that the single greatest reason for transactional service systems failing to absorb variety is a) *standardization* including scripts, procedures and standards (as opposed to employees with authority and one-stop capabilities to solve problems), b) *targets* (focusing on activity rather than on system purpose, i.e. measures from the customer point of view), and c) *decoupling* operations into front and back office. In summary, he reached the same conclusions as his American counterparts (Schlesinger and Heskett, 1991a, b; Heskett *et al.*, 1994) when 15 years in the past had discussed appropriateness of production-like approaches transferred from manufacturing to services.

The second important contribution is from Frei (2006) and her seminal paper: *Breaking the Trade-Off between Efficiency and Service*. The author first identified different types of customer-introduced variability, namely *arrival*, *request*, *capability*, *effort* and *subjective preference* variability. Consequently, she developed four basic strategies that service organizations could pursue and the corresponding tactics that have proven to be effective for each type of variability. The basic strategies include: *classic accommodation* and *classic reduction,* which represent the two opposite extremes assumed by many managers, that is, either accommodate customers' various desires and behaviors at high cost or refuse to accommodate variability with the risk of customer defection. Frei proposed two additional strategies that allow service managers to break free from the previous trade-off. These include *low-cost accommodation*, which includes tactics for offering a high level of accommodation at low cost (e.g. outsource service to low cost providers, create self-service options that require no special skills or allow customization) and *uncompromised reduction*, which includes tactics that reduce variability without damaging the service experience (e.g. target customers on the basis of their requests, capability and subjective references, use normative means to get customers increase their effort, etc.). Although not labeled as lean, the above work is close to the core of lean, since it discusses strategies to manage variability.

In terms of *guiding principles*, most authors agree that the lean philosophy and principles are universal and only the tools might change depending on the environment (Womack and Jones, 1996; Jones *et al*., 1999; Hines *et al*., 2004; Ahlstrom, 2004; Lander and Liker, 2007; Suárez-Barraza *et al.*, 2012). Other authors proposed principles dedicated to services[5], which are presented in Table 2.5 and include: the *consumption* of goods and services from the consumer's standpoint and ways to optimize it (Womack and Jones, 2005a,b) and *information flow* to create value in knowledge work (May, 2005).

Although the above principles provide valuable insights, they represent more a set of objectives, rules and behaviors an organization has to strictly follow. In contrast to this approach, Hopp and Lovejoy (2013) selected scientific principles (from various academic fields, namely engineering, decision making, quality, and human behavior) that stand to the

[5] We have excluded from this table those principles we consider to be tools or practices and discuss them in the next paragraph that is dedicated to lean frameworks (for example Ahlstrom, 2004; Wei, 2009)

test of time and are relevant to healthcare operations. The authors argue that these principles (although not labeled as lean), because they are timeless, they can predict the behavior and outcomes of operations, and, hence, help hospitals excel regardless of the policy regime in which they operate (Hopp and Lovejoy, 2013).

Table 2.5: Lean principles related to services

Area	Principle	Description	Source(s)*
Lean Consumption	Solve the customer's problem completely by insuring that all the goods and services work, and work together	Highly trained personnel should not only solve a problem but identify its systemic source, so that permanent fixes are put in place to solve the problem at the source	(1)
	Don't waste the customer's time	A problem should be looked from the customer stand point. A consumption map with all steps in the process should be drawn and the system should be reconfigured to eliminate wasted time	(1)
	Provide exactly what the customer wants	Systems should be put in place that replenish quickly and restock exactly what the customer has pulled from the shelf	(1)
	Provide what's wanted exactly where it's wanted	Using the information available to retailers for the purchasing habits of consumers can help them to put the right items in the right stores and to target the right customers	(1)
	Provide what's wanted where it's wanted exactly when it's wanted	Producers should encourage consumers to plan ahead and share their plans so that demand can be meat without disruptions	(1)
	Continually aggregate solutions to reduce the customer's time and hassle	The concept of reducing the suppliers and replace them with fewer that can solve more broader problems used in manufacturing can be applied in consumption as well	(1)
Lean Knowledge Work	Adding Value	This defining concept is the fundamental belief that individuals and organizations exist to create value for society by removing waste and building collaborative and engaging relationships with suppliers, customers, employees, stockholders and communities	(2)
	Creating Flow	This is the effective and efficient movement of tangibles (products and services) as well as intangibles (information and knowledge) to proactively engage customers in understanding and serving their needs	(2)
	Achieving mastery	This element focuses on meaningful growth and progress towards best performance through management of knowledge and continuous learning	(2)
Flow - Capacity	System Capacity	The capacity of a system is defined by its bottleneck, which is the resource in the system with the highest utilization. If the capacity of the system is less than the demand place on it, the demand cannot be met	(3)
	Utilization	Utilization magnifies queueing in a highly nonlinear fashion	(3)
	Batching	When tasks involve setup time, performing them in batches makes better utilization of capacity but also introduces waiting time for tasks following the batch	(3)
	Newsvendor	In a single demand period with uncertain demand, the capacity level that optimally balances the cost of too much capacity with too little capacity is given by Q^*, where: $F(Q^*) = c_u / (c_o + c_u)$ and $F(x)$ = probability that demand is less than or equal to x c_o = cost of overage, cost per unit overstocked relative to	(3)

Area	Principle	Description	Source(s)*
		demand c_u = cost of underage, cost per unit understocked relative to demand	
Flow - Variability	Variability	Unsynchronized variability causes queueing	(3)
	Variability Buffering	All unsynchronized variability will be buffered by some combination of inventory, capacity, time, quality and system degradation	(3)
	Variability Buffering in Service Systems (Corollary)	In a pure service system, inventory is not available as a buffer, so holding quality and system degradation costs constant, there is a trade-off between variability, excess capacity, and waiting time	(3)
	Buffer Flexibility	Flexibility in variability buffers reduces the amount of buffering required for a given amount of variability	(3)
	Little's Law	Over the long run, the rate (R), in-process inventory (I), and waiting time (T) of a system are related according to: I=RxT	(3), (4)
	Pooling	Combining sources of variability so that they can share a common buffer reduces the total amount of buffering required to achieve a given level of performance	(3)
Flow - Task Efficiency	Task Simplification	Reducing task complexity (i.e. the number of actions, precedence constraints, and information cues needed to specify it) reduces the mean and variance of the task times and the likelihood of errors	(3)
	Task Standardization	Using clearly specified best-practice procedures for repetitive tasks reduces the mean and variance of task times and the likelihood of errors	(3)
	Critical Path	In a process with parallel activities, the throughput time for the process is determined by its critical path, which is the longest of the parallel paths in the process	(3)
Flow - Sequencing	Critical Ratio Sequencing	In a multiclass system with dynamic arrivals, prioritizing entities according to the ratio c/t, where c is the delay cost per unit time and t is the expected process time, minimizes total cumulative delay cost over the long term	(3)
	SPT Sequencing (Corollary)	Processing entities in order of shortest processing time (SPT) minimizes average wait time	(3)
Flow - Protection	Redundancy	Independent layers of protection increase the reliability of a system	(3)
	Fool proofing	Using constrains to force correct actions reduces the likehood of errors	(3)
	Intuitive Information	Providing essential information visually or orally in tight association with a task reduces the mean and variance of task times, as well as the likelihood of errors	(3)
Information – Transfer	Handoffs	Unless new knowledge is contributed by individuals, information is degraded as it is passed from one individual to another	(3)
	Knowledge Sharing	Knowledge is power, so people need a good reason to share it	(3)
Information - Decision Making	Incidence Rate	The lower the incidence rate of a condition, the more likely a test is to yield a false positive result	(3)
	First Impressions	First impressions are critical inputs to decision making, because they are psychologically self-reinforcing and because even an objective statistician will not alter strongly held beliefs without significant contrary	(3)

Area	Principle	Description	Source(s)*
		evidence	
Information - Information Value	Value of Information	The value of information is determined by the ratio of the expected improvement in outcome with the information over the outcome without the information. This implies that information that does not change a decision has no value	(3)
	Test Quality	All else equal, tests with higher sensitivity and higher specificity are better in supporting rapid and accurate treatment	(3)
Behavioral - Cognitive Efficiency	Workload	Work efficiency and accuracy exhibit an inverted-U shaped relationship with workload	(3)
	Interruptions	Interruptions of complex tasks degrade the quality of decision making and the efficiency of execution	(3)
	Fatigue	Fatigue impairs decision making and task execution	(3)
Behavioral - Perception	Waiting Time Psychology	▪ Occupied time feels shorter than unoccupied time, ▪ People want to get started ▪ Anxiety makes waits seem longer ▪ Uncertain wait feels longer than known, finite waits ▪ Unexplained wait feels longer than explained waits ▪ Unfair waits feel longer than equitable waits ▪ The more valuable the service, the longer the customer will wait ▪ Solo waits feel longer than group waits	(5)
	Negative Experience	People react more strongly and more durably to negative service experiences than to positive ones	(3)
Behavioral - Individual Behavior	Self-Interest	Individuals, not organizations, are self-optimizing	(3)
	Hoarding	People hoard resources in uncertain environments as buffers against an uncertain future	(3)
	Inertia	People resist change because they know the system they are familiar with, but do not know firsthand the strengths and weaknesses of alternative proposals. Unless there are compelling reasons to believe that significant advantages will accrue, the certain status quo will be preferred to an uncertain future	(3)
Behavioral - Group Behavior	Key Stakeholders	All organizations have key stakeholders with veto power whose approval is necessary to implement changes	(3)
	Veto Power	For a proposal to be implemented, all key stakeholders must perceive themselves to be better off with the proposal than without it	(3)
	Pareto Efficiency	If benefits can be transferred from one group to another (for example, via the transfer of money or time or some other medium of exchange), and if there exists a policy that improves the overall performance of a system, there exists an allocation of total benefits that makes all key stakeholders better off	(3)
	Motivation for Change	Motivation for Change comes from a perceived or projected divergence between organizational performance and the goals of its key stakeholders	(3)

Area	Principle	Description	Source(s)*

* Sources: (1) Womack and Jones (2005), (2) May (2005), (3) Hopp and Lovejoy (2013), (4) Little and Graves, (2008), (5) Maister (2005)

Finally, researchers used *frameworks* to define LS. These frameworks are distinguished into *design* or *conceptual* (discussed below) and *implementation* (discussed in Section 2.4.2). The former constitutes several components that work synergistically to create a streamlined, high quality system that produces finished products and services at the pace of customer demand with little or no waste (Shah and Ward, 2003). For example, Duclos *et al.* (1995), identify six essential components of JIT in services: synchronization and balance of information and workflow, total visibility of all components of the process, continuous improvement of the process, holistic approach to elimination of waste, flexibility in the use of resources, and respect for people. Bowen and Youndahl (1998) suggest six components of LS: flexibility and responsiveness, focus on individual customers, value-chain integration and disaggregation, empowerment of employees and teams, knowledge management and networked organization. Ahlstrom (2004) identify seven LS components: elimination of waste, zero defects, pull instead of push, multifunctional teams, decentralization of responsibilities, vertical information systems, and continuous improvement.

More specific frameworks include those that measure lean maturity, such as the work of Malmbrandt and Ahlstrom (2013), and sector-specific frameworks such as the House of Lean for Public Services (Radnor, 2010), and the Lean Supply Chain framework (Jasti and Kodali, 2015b). The above models have been subject to criticism (Anand and Kodali, 2009; Gupta *et al.*, 2016), since they lack empirical evidence, comprehensiveness, thorough guidelines, and are sector or organization specific.

From the above analysis we conclude that although past literature provided powerful insights, these were based solely on the work done in manufacturing. This resulted to the same ambiguity found in the manufacturing literature in regards the essence of lean (Holm and Ahlstrom, 2010; Suárez-Barraza *et al*, 2012; Dos Leite and Vieira, 2015). In addition, past work in services has not been integrated with the lean body of knowledge, therefore we consider this as a major gap in defining LS.

We discussed in the previous paragraphs that service researches and practitioners adopted Ohno's seven wastes classification, to assign service wastes in one of the seven categories or added new ones not found in manufacturing (Womack and Jones, 1996; Liker, 2004; Bicheno, 2008). The limitations of Ohno's approach have already been discussed (Section 2.2.3) and include missing sources of waste (i.e. waste for all resource types, such as unutilized capacity, energy and space), and some inconsistencies (e.g. overproduction is a cause, while inventory a consequence). In addition, some activities cannot be defined as wastes up-front if better solutions have not been identified first (e.g. optimize transportation versus removing the need for transport).

Despite the criticism, it seems that the concept of waste has been well accepted by service researchers and managers. We present a summary of the typical wastes found in information-intensive services in Table 2.6. We have enhanced the list of wastes by incorporating the concept of waste as buffer (Hopp and Spearman, 2004; Hopp, 2013; Thürer *et al.*, 2016). According to this concept, waste is distinguished in a) execution (or obvious) waste, typically the result of resources not properly used, and b) coordination (less obvious or hidden) waste, typically associated with undesired excess (e.g. inventory, time and capacity above the level that maximizes profit and cash flow).

Table 2.6: Typical wastes found in information-intensive services (original synthesis and enhancement by the author from key works of Ohno, 1988; Chase and Stewart, 1994; Hopp and Spearman, 2004; Bicheno, 2008; Hopp, 2013)

Coordination vs. Execution waste	**Ohno's Wastes**	**Service Wastes**
Coordination (less obvious, hidden) waste	*Inventory waste*	*Unnecessary storage and filing* of information (or stored beyond retention period), that can be reproduced by other means, e.g. archiving print-outs that already exist electronically, or multiple copies of the same document in different places
	Time waste	*Time spent waiting* without any action taken, e.g. a document waiting to be reviewed, a customer waiting in a queue, an operator waiting to login to a system due to system outage
	Capacity waste (unutilized)	*Lost capacity* and the associated costs from resources (machines, people) that are being idle. Typically, the capacity level is determined by the one which optimally balances the cost of *over with under* capacity
Execution (obvious) waste	*Capacity waste (not properly used)* *Overproduction*	Doing more that needed or not needed at all, or not at the time needed: • *More work than needed or not needed at all,* e.g. producing a ten-page report, when the same message could be delivered in two, or creating things that are never used, e.g. software features, reports, tools, etc. • *Work not done at the time needed*, e.g. working on items of low priority, while there are more urgent things to work on, or work that could be performed in anticipation of demand (*Service inventory*)
	Over-processing	Over engineering things or adding complexity not required. • *Unnecessary complexity* i.e. work executed using methods, information and tools that are more complicated or expensive than necessary for its application • *Duplication* i.e. work done usually from (or for) different entities more than once. For example, re-assessing a legal term in a contract, which has been already assessed in the past, re-enter same information in multiple systems • *Excessive controls,* i.e. trying to identify mistakes after the work is done. Not only is this an expensive way to work but inspection control never picks up all errors • *Excessive authorizations,* i.e. "authority levels", according to which people have authority to "sign off" work up to a given financial level, while in many cases above this level the work is often not any different

Coordination vs. Execution waste	**Ohno's Wastes**	**Service Wastes**
	Transportation	*Unnecessary handoffs*, as a result of decoupling activities and in the absence of *one-stop* capabilities, e.g. a client, a document sent back and forth between departments
	Unnecessary motion	Poor ergonomics to support the service encounter, such as • *Sorting and searching*, i.e. work spent searching for something, such as information, documents, advice, etc. • *Interruptions* i.e. time to recuperate from interruptions in the workplace, e.g. calls, walk-in colleagues, etc. • *Batching* i.e. work waiting to be grouped in batches before it is sent to a downstream process
	Defects	Errors, omissions or quality issues that typically must be reworked: • *Task related,* e.g. work done incorrectly, wrong order, too slowly • *Treatment related* e.g. lack of acknowledgment, not listening or reacting inappropriately to the client • *Tangible related,* e.g. non-proof-read documents, uncontrolled facilities It includes also the associated costs of tasks that cannot be reworked (e.g. surgical errors, false diagnosis, etc.)
	Non-utilized skills	Non-utilized skills and capabilities, i.e. • *Simple tasks assigned to valuable resources*, e.g. work assigned to a senior employee while it could be automated or can be delivered by junior staff • *Time to on-board newcomers* and the associated costs e.g. as a result of frequent (more than industry average) turnover of employees

From the above Table, we highlight some notable observations. The first refers to *inventories*. As already mentioned, physical inventories do not exist in every type of service, since it is not possible to stock the transformed resource, the customer. However, Chopra and Lariviere (2005) argued that if we extend the inventory concept from a finished product ready to be purchased to *work done in anticipation of future demand*, then it is possible to consider *service inventories*; that is, information such as databases or decision support mechanisms that reduce the amount of work required when an order arrives. For example, credit rating agencies, databases of tax histories, which sell consumer data and credit scores to financial institutions, sometime perform part of a service before service request has arrived, therefore, represent service inventory. Although this concept[6] can be useful in service operations, the amount of work that can be performed in anticipation of service demand may vary between different service types, therefore, it is questionable if it can have similar impact as inventory reduction had in manufacturing.

A second observation is that the above wastes refer primarily to internal service activities. However, as already discussed, in services customers play a central role either by actively

[6] The concept of performing work in anticipation of future demand resembles to the SMED methodology, where internal activities are converted to external and performed before the setup commences.

participating in service delivery or by performing the service themselves (e.g. self-services). Therefore, the wastes listed above should be seen from the customer standpoint and not only as part of the internal processes of the service organization. One of the few exceptions in the literature that do consider customer-related waste is the work of Womack and Jones on *service consumption* (2005a,b) presented in the previous Section. The authors identified five principles centered on minimizing the time and effort of the customer during service delivery. However, these principles have not been incorporated in the waste typologies nor have been highlighted enough in the past LS literature.

Finally, the wastes found in the service literature are primarily derived from manufacturing and do not necessarily consider wastes specific to services. One such example is *turnover* of service employees. This has been mentioned as one of the biggest challenges in service organizations (see *cycle of failure* by Schlesinger and Heskett, 1991a, b); however, this topic has not been explored in the context of LS literature. We discuss the above topics more in detail, along with other limitations of LS in the following Section.

2.3.3 Limitations and extensions of lean in services

In Section 1.2 we discussed the main challenges in service design and management derived from the distinct nature of services, namely the intrinsic variability due to *customer participation* and *server dependency*, *labor intensity*, *stockability*, and *simultaneity of production and consumption*. In practice these characteristics are present at various levels in all kinds of environments from *pure products* to *pure services*. Consequently, it would be reasonable to expect that depending on the strength of these characteristics, they would influence the general applicability of LM in services. We discuss bellow some notable limitations and extensions (i.e. challenges not found in manufacturing) of applying LM in services, mapped in the six distinct managerial areas defined in Section 1.2.

2.3.3.1 Service package and process design

Probably the most cited factor that limits the extent of service rationalization is the variation inherent in the human interactions, a result of *customer participation* and *server dependency* (Chase and Apte, 2007). Given that the reduction of (unnecessary) variability is at the core of lean, this creates two important implications. The *first* is that service organizations need to focus not only on the efficiency of service delivery (as in manufacturing) but also on *customer experience* as customers participate in service creation. This is an aspect not found in manufacturing. Suárez-Barraza *et al.* (2012), argue that every service encounter is a *moment of truth*, a situation experienced differently by each the customer, therefore all the necessary elements (such as skills and capabilities of the personnel, attitude, quality of service, etc.) to meet customer needs should be integrated in service delivery. The value delivered consists of the solution delivered, the benefit obtained by the customer and the treatment received. Additionally, as discussed in the previous Section, wastes in service processes should be assessed from the customer point of view as well. Furthermore, customer involvement in services may imply that what may seem as waste of the service process might to some customers be adding value to their experience (Ahlstrom, 2004).

The *second* implication is the extend that *standardization* can be used as a strategy to reduce variability in services. Standardization has been considered an integral part of TPS and a prerequisite for continuous improvement (Ohno, 1988). The paradox with standardization in Toyota is that while it depends on highly standardized routines and methods for ensuring efficiency, at the same time it functions as a basis for flexibility (Adler, Goldoftas, and Levine, 1999). This is achieved by standardizing parts and tasks at the lowest possible level and reusing them across product families. Liker and Morgan (2006) defined three levels of standardization, including: *design*, i.e. designing common architecture, modularity, reusability, and shared components; *process*, i.e. designing products and facilities based on standard manufacturing processes; and *skills*, i.e. predefined skill sets for the engineers for planning/ staffing flexibility and less task variation. On the production floor *work standards* are used extensively to describe the best and most reliable methods and sequences to perform a job; this results to reduction of variability amongst employees (in terms of lead-time, improved quality and output consistency), and less time and cost to onboard (new), and cross-train (existing) employees (Ohno, 1988; Spear and Bowen, 1999).

While the *standardization vs. flexibility trade-off* has been well understood and applied in Toyota, in services standardization has produced mixed results. In terms of *service design*, the concept of *service modularity* has not been explored to the same degree as in manufacturing, although it has drawn the attention of service researchers in recent years (for a literature review see Iman, 2016; Brax *et al.*, 2017). In terms of standardizing *customer interaction,* there might be potential adverse effects both on customers as well as to service employees. For instance, following scripts and procedures instead of understanding and solving customer problems, decoupling work into routine, highly standardized tasks with limited discretion, contacting multiple servers in order to address a wide variety of needs, all these *production-line* practices may impact *customer experience*, *quality* in services and employees (Bowen and Youndahl, 1998; Chase and Apte, 2007; Seddon, 2005; Seddon and Caulkin, 2007; Seddon *et al.*, 2011; Victorino *et al.*, 2013). Indeed, anecdotal evidence suggest that dialog scripting and close performance monitoring combined with work design characteristics such as lower control over work methods and timing, lower task variety and skill utilization, higher workload, role conflict and lower role clarity can cause job-related strain to call-center agents (Sprigg and Jackson, 2006).

In terms of *work standards*, past research suggests that services are not necessarily unpredictable and hence can be standardized to a certain degree (Sampson and Froehle, 2006; Seddon 2011). For example, Hopp and Lovejoy (2013) argue that work standardization should be applied to repetitive processes and most importantly to repetitive decisions. Bicheno (2008) suggests that standardization can take many forms (not just work procedures), and only the critical steps – i.e. those prone to quality mistakes or those critical for customer satisfaction - need to be standardized. Seddon (2011) argues that standard work methods and best practices should be defined by employees who are performing the work and should not be imposed by the managers.

However, the challenges to standardization arise when service delivery becomes more human dependent or intellectually-oriented. For example, in complex, intellectual tasks it is almost impossible to predefine all possible outcomes. Hopp *et al.* (2009), argue that proven methods from blue-collar settings, which rely on standard operating procedures and do not take knowledge and information as inputs, cannot be applied directly to white-collar work systems. In any case, standardization in services is a critical design consideration and more explicit guidelines on *where*, at *what* degree and *how* to apply standardization are needed.

2.3.3.2 Buffer management

Another limitation of services is the *available buffers* to address variability. As already discussed, variability in a production system can be buffered by a mix of three types of buffers: *inventory*, *capacity*, and *time* (Hopp and Spearman, 2004). Given the overall objective of any business for long-term profitability, it is becoming critical to understand the best combination of inventory, capacity, response time and variability. Sometimes it makes sense to increase "waste” (inventory) if that achieves the overall profitability goal (Pound *et al.*, 2014). Although in manufacturing the relationships between those parameters have been explored, in services such an investigation has not been performed.

In the next paragraphs we clarify a few important concepts related to the three buffers in services and the underlying implications.

First, in terms of the *inventory buffer*, there is a significant amount of services were inventories are not part of the core service offering. By inventory we refer to *finished goods,* ready to be purchased, that are produced in anticipation of future demand. We do not refer to *service inventory*, i.e. work that can be done in anticipation of demand, which does not include any *physical component*. This implies that variability in services can be buffered by *capacity* and *time*. Most importantly, the benefits of LM from the reduction of inventories and the associated reserved capitals cannot be achieved in services; thus, the equivalent benefit in services will come from the reduction of *capacity* and/ or *time*.

Secondly, by *capacity buffer* we refer to the different capacity resources, such as employees or machinery, required to perform the related service tasks. Noting that in services unused capacity is forever lost, it is becoming critical to synchronize capacity with customer demand (Gronroos 1988, Vargo and Lusch, 2004). Furthermore, the customer represents an additional resource since certain steps in service processes can be performed by them. Hence, offering self-service options or designing services that require customers to perform certain steps prior to the service encounter can help reduce the capacity requirements for the service organization. A typical example in the service literature is *Shouldice Hospital* (Heskett, 2002), a best-in-class hospital specialized in hernia operations, which requests from patients to perform certain steps prior to surgery (e.g. participating in weight loss programs).

Thirdly, by *time buffer* we refer to the time a customer needs to wait before receiving a service. For example, customers waiting in queue although they may be thought as *work-in-progress* (WIP) inventory, it is more accurate and useful to consider them as time buffer. However, there is an important detail: service organizations can actually control the amount of WIP entering in their system. This is the underlying essence of *pull*, a concept discussed in the next Section.

Finally, Hopp, Iravani and Yuen (2007) argue that many service and professional systems involve less-defined tasks with discretionary completion criteria. This introduces a degree of flexibility into process times, allowing a worker to adjust the quality of his/ her output to manage workload. Hence, in addition to the well-known buffers of capacity, inventory and time, *quality becomes a fourth buffer to manage variability*, leveraging discretion in task completion. The authors reach several striking conclusions for systems with discretionary task completion: a) adding capacity may increase congestion, b) adding input task variability may improve system performance, and c) the benefit of queue pooling is less pronounced than in systems with non-discretionary task completion.

From the above we conclude that the selection of the right mix of buffers, considering quality as a fourth buffer, is an important topic in service operations. However, to the best of our knowledge, this has not been investigated in the past service literature. We discuss the important role of quality as part of quality management in Section 2.3.3.4.

2.3.3.3 Scheduling and queueing

In terms of queuing, we have already discussed in Section 1.2 the importance of managing the psychology of people waiting in queues as well as the visibility of non-physical queues. In Section 2.3.2 (Table 2.5) we have also presented the basic queue psychological laws, as introduced by Maister (2005). Additionally, past research suggests that the introduction of LM concepts in services may negatively affect customer experience. For example, in a cellular structure, although the total time in the system is likely to be shorter, the initial waiting period prior to first contact may be longer; this latter fact is typically perceived negatively by customers who are less tolerant in waiting prior to initiating system operations (Harvey, 1989; Pagell and Melnyk, 2004). Therefore, managing customers' perceptions and expectations is an important aspect in service operations. Obviously, this is a challenge not encountered directly in manufacturing.

In terms of scheduling, we have already discussed the confusion around *pull* and *push* in Section 2.2.2. Unfortunately, this confusion affected the LS thought. For example, Malmbrandt and Ahlstrom (2013) argue that pull is seen as the signal that initiates work to be performed in order to deliver a service. Radnor (2010) suggests that it is open to debate whether it is in fact possible to use the pull principle in services, given that services are produced and consumed simultaneously. Leyer and Moormann (2014) argue that it is surprising that the pull approach is not really applied.

The authors above, similarly to authors and practitioners in manufacturing, consider the benefit of pull the *act of pulling* (i.e. the downstream process requests jobs, parts, information etc. from the upstream process) or the *devices* with which pulling is performed (e.g. physical, or electronic boards and kanban cards), instead of the actual control of WIP (Hopp and Spearman, 2004). In manufacturing, for example, by keeping WIP low (or constant) one benefits from reducing cycle time but (due to Little's Law) it comes with a reduction in throughput as well. Additional benefits from controlling WIP include the lesser space required (as a result of reducing WIP) and the quality issues revealed (as a result of having to work and examine, for quality purposes, less items).

In information-intensive services, which are similar to make-to-order environments in manufacturing, jobs are typically released without taking into consideration the state of the system (i.e. push system) causing in several occasions congestion or long queues. Furthermore, the openness of service systems (Fitzsimmons and Fitzsimmons, 2005), permit customers who experience failures to return directly to the service production system, causing major disruptions; that is, queues create more queues, i.e. the number of interruptions (phone calls or emails from returning customers) is directly associated to the number of activated tasks.

So how can one apply pull to an information service setting? One possible way would be to release jobs into the service system by taking into consideration the state of the system, i.e. using blocking mechanisms to prevent jobs releases when the system is overloaded. A well-known example is to inform customers about the queue length and expected waiting time, so that they don't enter the queue if they are not ready to wait for that long. Other examples include limited reception areas or waiting spaces in banks, fast food restaurants, etc. A limited space may regulate the number of customers entering in the system, and thus prevent it from been overloaded.

For instance, in a workflow system of two stations a certain limit may be set on the buffer queue between the two stations. When that limit is reached, all operators in station 1 stop taking new requests/ clients and start helping operators in station 2 until the intermediate buffer queue is cleared. Of course, if such situations occur too frequently, a more permanent solution should be sought (Harvey, 1989). Overall, if you reduce the number of job releases in a system (or control them) one might lose in throughput but may gain in cycle time, quality, and productivity. The concept of pull, as derived from the current literature review, have not been investigated thoroughly in the context of LS and need further investigation.

2.3.3.4 Quality management

Service quality is another important area that entails limitations when applying LM concepts in services. In manufacturing, quality is considered one of the basic requirements for successful implementation of JIT. Performing tasks *right the first time*, and continuously working to solve quality-related problems are at the heart of LM. In services, although lean practices (such as *error-proofing* and *visual control*) can reduce variability and prevent failures (Chase and

Stewart, 1994; Sampson and Froehle, 2006), for certain types of services there are some challenges in properly *defining*, *measuring* and *managing quality*.

The *first* challenge relates to the *intangible and complex nature* of many services. This may oftentimes lead to customer dissatisfaction (Kelly *et al.*, 1993). For example, in the professional service industry several years of experience and use of judgment are required to deliver a *zero-defects* service due to its complexity (Apte and Goh, 2004). Additionally, the severity of failures might be different, ranging from a serious incident, such as a wrong medical prescription, to less significant problems, such as short delays (Kelly and Davis, 1994).

The *second* challenge relates to *customer participation*. The variability introduced by the customer makes the quality of service more uncertain. For example, customers assess service quality based on past experiences and using their own criteria; this creates a shifting foundation when trying to accommodate different needs (Frei, 2006). Additionally, in information intensive services, the quality of service depends on the information provided by the customer. In insurance services, high quality information (including accuracy, timeliness, relevance, quantity, and form of information) is critically important for reaching correct decisions and for taking appropriate actions (Apte and Goh, 2004). This implies that operational processes must be continuously monitored, analyzed and improved to obtain high quality information from customers (Maleyeff, 2005).

The *third* challenge relates to the impact of *service employees* on quality. Past research has highlighted a *tradeoff between processing speed and output quality*, as certain characteristics of the service environment change. For instance, Oliva and Stearman (2001) and Oliva (2001) argue that one of the ways service workers choose to respond to changes in work pressure is by reducing the time allocated to each customer. To do so, they attempt to process each customer faster either by accelerating their speed or by *cutting corners*, that is, eliminating non-essential or even core aspects of the service delivery process. The authors concluded that in the long-run such practices eventually erode service quality; they have also explored policies and implications for organizational design in order to improve performance in the service sector. Kc and Terwiesch (2009) use operational data from two vastly different healthcare delivery services (patient transport and cardiothoracic surgery) and illustrate that processing speed of service workers is influenced by system load. They find that workers accelerate the service rate as load increases; however, such acceleration may not be sustainable. Long periods of increased load (overwork) have the effect of decreasing the service rate, but, most importantly, overwork is associated with an increase in likelihood of mortality. In financial services, intended mistakes (i.e. fraud cases) represent an additional concern.

From the above we conclude that quality plays an important role in service operations. Although the topic of service quality has been investigated extensively in the past, this has not been done in the context of lean operations. For instance, Hopp *et al.* (2009) suggest that increasing worker capacity may result in higher system congestion, as a result of the lower quality, introduced variability and time to onboard newcomers; therefore, it may be more optimal to use extra capacity to improve task quality. Based on the above, identifying policies that make optimal use of variability buffers, including quality as a fourth buffer, is a topic requiring further investigation in lean service operations.

2.3.3.5 Performance management

In terms of performance management, we have discussed in Section 1.2 the importance of more sophisticated performance assessment approaches, as the complexity of tasks and human input increases in services. Indeed, Chase and Apte (2007) argue that early scientific management attempts in service industries were not as successful as in manufacturing due to the resistance by white-collar workers and the challenges to measure, monitor and control service processes (e.g. not easy to predict the exact number of customer orders or the content of customer requests).

Maleyeff (2005) argues that the duration of certain tasks in service systems is often highly variable, making it a challenge to create standard process maps and use some of the lean techniques, such as *takt-time*. In a similar vein, George (2003) suggests that in service environments it is difficult to quantify the quality and speed of work on an average basis, because it is influenced by many unpredictable factors. Hopp *et al.* (2009) argue that the outputs of white-collar work are particularly difficult to measure or value economically until long after the completion of tasks. This is a problematic area for service managers that limits the ability for sufficient decision-making, such as capacity management and planning. On the empirical front, Piercy and Rich (2008) study three cases in the financial sector and suggest that arbitrary performance measures reinforce the negative behavior of servers, leading to inferior customer service and increased costs.

Finally, Hopp *et al.* (2009) suggest that given the high level of worker autonomy, a large variation in work performance is expected amongst white-collar workers; this implies that incentives can be extremely important in motivating worker behavior. However, in contrast to blue-collar workers, different incentives may be appropriate; these include peer recognition, self-advancement, and exposure to smart colleagues, learning and adoption of new technologies. From the above we conclude that several insights while existent in the literature, they have not been incorporated in the LS literature.

2.3.3.6 People and organization management

An agreed theme in service operations is that employees who are well trained and fairly compensated provide better service without much supervision, and stay longer on the job; consequently, they are well accepted by customers (Schlesinger and Heskett, 1991; Canel, Rosen, and Anderson, 2000). Suárez-Barraza *et al.* (2012) argue that lean practices invest significantly in developing employees through mechanisms of involvement and participation at the team level and at the individual level. Ahlstrom (2004) suggests that working in multifunctional teams is key in people-based services, while Hopp, *et al*. (2009) argue that because the complexity of white-collar jobs is high, frequent interactions and trust with other team members are needed to acquire necessary information and work-related knowledge.

Flexibility and empowerment of employees are recognized as key components of lean services. However, since learning can be slower in (some) professional services, it may be difficult to have team members rotating among all tasks in the team (Ahlstrom, 2004). Furthermore, more sophisticated information management systems are needed. Asif, *et al.* (2010) identify knowledge management as one of the key challenges for implementing lean in knowledge-based environments. In particular, flexible and practical mechanisms are needed to create, store, retrieve, transfer, and integrate knowledge. Finally, given that several decisions need to be made during the service encounter, Ahlstrom (2004) emphasizes the need for employees to have the authority to make these decisions, and supports the principle of decentralized responsibilities.

2.4 Transferability of lean manufacturing concepts to services

In the previous Section we reviewed the *applicability* of LM in services, including important *theoretical and conceptual* contributions. In this Section we examine the *transferability* of lean in services, including implementation cases by service *sector, function* and *LM practice* and the implementation approaches, including aspects such the *scope* and the *sequence* of implementation (we use the terms implementation, transformation and adaptation interchangeably). Subsequently, we discuss the *challenges* to overcome in order to ensure a successful implementation.

2.4.1 Implementation cases and impact on performance

In this Section we provide an overview of LM implementation in services and specifically a) the areas in which LM has been implemented by service sector and function, b) the LM *practices* (tools and methods) that have been implemented, as well as c) their associated *impact* on performance. Given the extensive research on the topic, the analysis focuses on the most cited sectors and functions.

2.4.1.1 Healthcare

Healthcare is the service sector in which the greater number of lean studies have been published (for an extensive literature review see De Souza, 2009; Mazzocato *et al.*, 2010; D'Andreamatteo *et al*., 2015; Costa and Filho, 2016). This is probably due to the importance of healthcare on human well-being, as well as the pressures to reduce costs in response to reductions in healthcare government spending (Radnor and Walley, 2008; Holm and Ahlstrom, 2010). Similar to manufacturing, most of these studies have been applied on *specifics units, or processes* (Mazzocato *et al.*, 2010; Burgess and Radnor, 2013; Rich and Piercy, 2013; Costa and Filho, 2016), and less on *system-wide* transformations. Indicatively, the areas mostly cited include *clinical* and *therapeutic* operations, while *ancillary* and *support* areas are less cited, even though the latter two bear distinct similarities to manufacturing (Costa and Filho, 2016). In some literature reviews, *surgery* and *emergency* care account for more than half of the reviewed studies, while *hospital pharmacies*, *laboratories* and *radiology* are the most cited cases within ancillary services (D'Andreamatteo *et al*., 2015).

Quality issues, such as surgical errors, wrong diagnosis and medication as well as infections, *high attrition* and *overburden* of employees, *rising costs* of equipment and medical supplies are some of the primary reasons for healthcare organizations to embark on lean initiatives (Joosten *et al.*, 2009; Dahlgaard *et al.*, 2011). Specific to quality, the scale and type of defects include (Berwick, 2008): high rates of unscientific care, inappropriate care, geographic variations in practice, latent disaggrements among specialists, and often unrecognized medical injury to patients. This probably explains why most lean studies are implemented in clinical and therapeutic operations (primary revenue generators), since in those areas the impact is expected to be higher (Costa and Filho, 2016). For example, according to

Spear (2005) the annual cost of medical errors in the U.S. is estimated between $17 to $29 billion dollars, while the savings from reducing errors through LM could be significant.

In terms of *lean tools and methods*, the majority of lean healthcare studies exploit a limited number of tools, with the most commonly used been (as in manufacturing): *value stream mapping*, *standardized work*, *rapid improvement events/Kaizen event* and *process mapping* (Mazzocato *et al.*, 2010; Costa and Filho, 2016). There are also other LM practices that, although not labeled explicitly as lean, have been implemented and found highly successful. These include *JIT concepts* for reducing inventories of medical supplies (Yasin *et al.*, 2003; Schonberger, 2007), *daily huddles* for improving the cooperation and coordination of healthcare professionals (Cooper and Meara, 2002; Picciano and Winter, 2013; Shunk *et al.*, 2014), *cellular layouts* (Hyer and Brown, 1999; Pagell and Melnyk, 2004), *surgical smoothing* (KC and Terwiesch, 2017), *scheduling* (Visintin *et al.*, 2017) and *changeover reduction* (Meredith *et al.*, 2011) for improving quality and patient flow. In particular, it has been argued that some of these practices had a major impact in the way healthcare is delivered, such as the introduction of a *readiness meeting* with all related personnel, before a surgical operation takes place in order to validate the availability of all equipment, and review the specific characteristics of the operation and of the patient.

Regarding the relevance of LM practices to healthcare settings, there are various views. Manos *et al.* (2006) argue that most LM tools and methods are applicable to healthcare and have provided a list of 18 LM tools that could be used in this field. Other authors argued that most LM tools could be applied in healthcare with minor adaptations (Costa and Filho, 2016). For example, Henrique *et al.* (2016) modified value stream mapping to include support activities for the patient flow that directly impact treatment time. New tools emerging from the implementation of LM concepts in services typically include (self) assessment methodologies to measure lean adoption, as well as to identify critical areas to improve (see for example Dahlgaard *et al.*, 2011).

In terms of *impact* on performance, according to Costa and Filho (2016), the most frequent results include time (waiting and length of stay) reduction, cost reduction, and capacity increase. According to D’Andreamatteo *et al*. (2015), from 167 analyzed studies over 50% referred to increased productivity and cost efficiency, with the other two principal outcomes including patient safety (18 cases) and financial outcomes (19 cases). Surprisingly only a few papers reported increased staff satisfaction, staff safety and negative effects. Indeed, the absence of cases in which organizations failed in their lean efforts has been highlighted as a major concern both in manufacturing (Marodin and Saurin, 2013) and service (Suárez-Barraza *et al.*, 2012) research. Furthermore, the fact that most lean implementations focused on a limited number of tools and units, implies that the *holistic view* emphasized in LM literature is missing in many reported cases. Consequently, healthcare researchers suggest that, despite the success of past efforts, the findings so far do not allow generalizations of the positive impact, or best approaches and effort required to implement LS in a healthcare context (D'Andreamatteo *et al*., 2015; Costa and Filho, 2016).

2.4.1.2 Financial services

Within Financial Services, Banking and Insurance are the two sectors mostly researched in lean implementations studies. However, unlike other service sectors, such as healthcare, there are limited documented cases and systematic reviews of efforts made during the past years in financial service industry, especially after the global financial crisis of 2007. One of the few literature reviews include the work of Vashishth *et al.* (2017). According to the authors, financial service companies turn to LM concepts to improve their operations, increase productivity, reduce response time and increase customer satisfaction. The implementation of lean initiatives covers mainly *core banking and insurance* operations, such as *branch units, loan processing units*, *insurance processing of claims units* and support functions such as *call centers* and *IT*. *Quality issues*, *unnecessary processing* and *handoffs*, *high attrition* and *long lead times* are some of the main concerns faced by financial service professionals. In the absence of systematic reviews, we refer to some relevant cases.

In banking, Yavas and Yasin (2001) report a 32% improvement in customer satisfaction and 35% reduction of customer complaints, as a result of the application of four LM tools (root cause analysis, benchmarking, process re-engineering and continuous improvement). Allway and Corbett (2002) report a 20% productivity improvement and about 50% reduction of processing throughput time in the commercial and automotive loan-processing center of a financial institution, as well as savings of more than $7 million annually in an investment bank by reducing trade *breaks (*i.e. cases in which trades cannot be completed). Erdem and Aksoy (2009) report a 22% reduction in lead time, 33% increase in throughput, and freed up capacity by 20% in branch operations of the national state bank resulting from the implementation of LS, namely process mapping and process re-engineering. Wang and Chen (2010) applied lean with six-sigma to reduce the waiting time to open a savings account by 32% and saved $0.83 million in a representative savings bank.

Swank's (2003) seminal paper in LS, *the lean service machine* related to operations in the insurance industry. Her study refers to Jefferson Pilot Financial, a U.S. life insurance company that managed to improve significantly its performance by applying LS concepts. Specifically, the company managed to reduce the cycle time of issuing a policy by 70%, reduce labor costs by 26%, and reduce reissues due to errors by 40%, while increasing employee and customer satisfaction. The LS practices employed include *cellular structures*, *takt time* paced work, *standardization*, and *performance metrics*. Another empirical application in this sector is reported by Hameri (2011), in which an insurance company restructured its claim processing unit and clustered its resources to *cells*. Significant benefits included the reduction in lead time and work-in-process (in some cases up to 77%), lower process variability and higher employee satisfaction. In call centers, Piercy and Rich (2009a, 2009b) presented three cases in financial institutions (insurance and banking), where the application of LS practices (*value stream mapping*, *process redesign*, *cross-skilling* and *continuous improvement*) led to reductions of the average time to complete a customer enquiry by half, and to increases in customer and employee satisfaction.

Similar to manufacturing, most of these studies have been applied on *certain units, or processes*, and less on *system-wide* company transformations. Although this author is familiar with a few banks that went through company-wide transformations, these have not been documented in the literature.

In terms of *lean tools and methods*, most studies employ a selected number of tools, with the most commonly used been (Vashishth *et al.*, 2017): *value stream mapping*, *standardized work* and the *basic continuous improvement tools* (such as Critical-to-Quality analysis, Supplier-Input-Process-Output-Customer, Process flow chart, Pareto analysis). According to this author's experience most of the LS tools have been applied with different success in financial services. *Two practices* that have had limited applications (as in manufacturing) include the practice of *pull* and *demand smoothing*. For the latter, one notable reference includes the work of Hatzakis *et al.* (2010). The authors refer to a credit card company that managed to smooth workload in remittance processing and call centers (daily volumes could fluctuate between half a million and one and a half million mails and calls) and reduce the associated high overtime and idle time. The company achieved that by re-distributing the cycle in which customers were notified about their bills[7]. The authors also provide a wide range of areas in which several optimization approaches have been successfully applied in financial services, such as inventory models to cash and currency management, optimization of banks distribution network, etc. Similarly, Apte *et al.* (2010) investigated the impact of various claim characteristics on performance metrics and found that early claimant contact can significantly reduce the chance of attorney presence (which has the largest impact on process performance). Unfortunately, such insightful cases although documented in the literature, they are not labeled as lean, and hence it is a challenge to track them.

In terms of *impact* on performance, the top 75% of the reported benefits, include operational ones such as reduced costs, reduced delays and improved cycle time, and improved service quality (Vashishth *et al.*, 2017). Like healthcare, no studies were found reporting failures in lean implementations. Despite the impressive results of the selected case studies, the anecdotal findings do not allow generalization of the positive impact and best approaches to implement LS in financial services. For example, according to a recent survey of financial service professionals in Germany, managers and employees overestimate their lean capabilities, in the sense that while they have the intention for acting in a lean way, this intention is not supported by concrete actions in this regard (Leyer and Moormann, 2014).

2.4.1.3 Transportation and logistics

Several benefits have been cited in the literature from the adoption of lean practices in supply chain activities such as *procurement*, *warehousing* and *distribution*. For instance, Ugochukwu *et al.* (2012) mentioned the following: *low inventories* (mentioned in 20 articles), *customer satisfaction* (mentioned in 12 articles), *optimized efficiency* (mentioned in 4 articles), *high quality* (mentioned in 22 articles), *reduced cost* and improved delivery regarding *time, quantity and quality* (mentioned in 26 articles each), and *high flexibility* (mentioned in 10 articles). LM concepts in supply chain activities have been examined primarily in the context of manufacturing companies and focused on *customer* and *supplier integration*. These practices are presented in Table A. of Appendix A. Here we focus on empirical applications of LM concepts in *transportation* and *logistics* companies or the related functions of manufacturing

[7] Previously customers were distributed into about 25 cycles, one for each working day of the month. For example, customers in the 17th cycle are billed on the 17th working day of the month. Customers in the same zip code were assigned in the same cycle so volume-mailing discounts from the US postal service can be obtained, and the cycles are level loaded. However, this allocation to cycles was no longer evenly distributed as over time some customers had closed their accounts while new customers had been added to existing cycles, resulting in large differences in the numbers of customers in the various cycles, and in a wide variability in the printing and mailing of monthly statements.

companies, while in the following Section we discuss lean practices in retail supply chain activities.

In the *transportation* sector there are a few cases related to airline companies, mostly to lean practices applied in *ground operations*. Hutchins (2006) presented the case of United Service, the aircraft maintenance division of United Airlines, which applied LM concepts to maintenance. These efforts increased capacity and response times allowing the company to attract new customers and recover from near-bankruptcy. Similar cases have been mentioned by other authors (Greenwood, Bradford, and Green, 2002; Reinardt, 2007; Newton, 2007). Surprisingly, well established practices in the industry, such as *yield management* that is used to smooth demand, have not been reported in the lean literature although there are closely related to lean (Duclos, Siha, and Lummus, 1995).

In the field of *logistics*, a few empirical applications have been reported. For example, Jones, Hines, and Rich (1997) introduced the term *lean logistics* and examined Toyota's parts supply system, which included, amongst others, a daily ordering system, parts stock held at a local distribution center, warehouse organized with similar logic to the Toyota factories and parts delivered to dealers four times a day. The authors examined the application of Toyota's distribution practices in a leading industrial distributor and estimated savings more than £10 million per year, equivalent to 20 percent improvement in profitability. Reichhart and Holweg (2007) investigated lean in the distribution system of a vehicle manufacturer and concluded that by applying different strategies by market segment can resolve some of the conflicts between lean distribution (responsiveness) and lean production (efficiency).

Lee *et al.* (2008) presented a case study of a 3rd Party Logistics (3PL) provider that managed to reduce labor expenses from $67 to $7 million by utilizing the lean management tools of JIT, Kanban, and VMI (Vendor Managed Inventory). Villarreal and Rosas (2009) used value stream mapping and root cause analysis to remove wastes and increase vehicle utilization of a Mexican food distribution company. Benefits included 25% reduction of shipments, equivalent to 1.8 million pesos per year. Sternberg *et al.* (2012) developed a waste framework for motor carrier operations by adapting the classical seven waste framework and validated it through empirical data of five motor carrier operators. They concluded that 29 percent of the transport time is either partly or completely wasted. Sharma and Shah (2016) investigated the application of lean methods to improve warehouse operations.

2.4.1.4 Retail

The adoption of lean in the retail sector is highly related to reducing inventories and stock outs, while optimizing supply chain operations. We present empirical applications in the two main types of retailers (Retail Trade: NAICS 44-45, 2017): *store* i.e. fixed point-of-sale locations and *non-store* retailers i.e. selling from portable channels such as the internet, vendor machines, etc. Store retailers are further distinguished in super markets as well as in companies having their own store network.

As discussed in Section 2.3.1, big (super market) retailers such as *Wal-Mart* in the U.S. and *Tesco* in the U.K. were amongst the first to adopt JIT concepts outside manufacturing (Womack and Jones, 1996; Schonberger, 2007). These approaches gained significant popularity in the retail industry and evolved to retail movements. For example, *Efficient Consumer Response* (ECR), *Ventor-Managed Inventory* (VMI), *Continuous Replenishment* (CR) and *Collaborative Planning, Forecasting, and Replenishment* (CPFR) were some of the approaches aiming to improve coordination among members of the supply chain through collaboration, information exchange, and common action plans. (For a complete discussion see Lee *et al.*, 2008).

In terms or companies that operate their own retail store network, *Zara*, the Spanish fashion company, managed to establish an agile supply chain which incorporates many *lean characteristics* and is considered the most effective quick-response system in its industry (Christopher, 2000; Fernie, Sparks, and McKinnon, 2010). The system can respond to large demand fluctuations and deliver products in 15 days worldwide (Lee *et al.*, 2010). The company utilizes the following (Christopher, 2000): *cross-functional teams* to produce designs according to the latest international fashion trends; *quick response manufacturing* for the most appealing clothes (around 60%) made by highly automated factories and by a network of more than 300 small subcontractors (working exclusively for Zara) the remaining clothes (around 40%) are imported as finished goods from low-cost countries; *postponement*, that is carrying inventory in a generic form (standard semi-finished products) awaiting final assembly or localization in order to offer high variety at a lower total cost; *close relationships* with a network of key suppliers able to synchronize their production and deliveries with the requirements of the company; finally, *reduced product complexity* in terms of *design* (e.g., the number of nonstandard components in a product) and excessive *variety* that does not justify its cost.

In terms of smaller retailers, Noda (2015) investigated the adoption of lean operations and argued that in order to compete with big competitors, small retailers need to combine LM concepts with constant pricing policies. Modig and Kosuge (2007) investigated how LM concepts have been adopted within the Toyota car dealer industry in Japan. The findings suggested that lean can be adopted within services and reach similar results as within manufacturing; however, the underlying practices to be applied will be determined by customer needs. Kim (2013) investigated the application of LM concepts (primarily root-cause problem solving) in a retail store offering donuts, in order to reduce long queues and improve customer experience.

Finally, a notable example of lean supply chain operations of non-store retailers, is Dell's operating model. Dell assembles computers (desktops, laptops, etc.) to custom specifications and sells branded computer peripherals and consumer electronics (monitors, printers, televisions, etc.). Some of the distinguished characteristics that differentiate Dell from traditional manufacturers include (Paxton, 2004): selling directly through the *most efficient path to the customer*, i.e. customers placing orders directly to Dell's webpage; *assemble-to-order* production with all of the product components (even those labeled as Dell) made from other contract manufacturers and assembled by Dell; *close collaboration with its suppliers*, to ensure that essentially no finished goods inventory is held; *single point of accountability*, where customers are able to get solutions quickly and use of *standards-based technology* to reduce unnecessary variability.

2.4.1.5 Information technology

Information Technology (IT) is one of the areas where LM concepts have been extensively applied, primarily to the *software development process* either at the company level or in in-house IT departments of companies. *Quality issues* and *defects* that remain undiscovered until later stages, and their consequences, is probably the primary waste encountered in the software development process. We distinguish the literature into two major streams: the first refers to the *methodological aspect* of lean in software development and its relevance to other approaches such as agile development (XP, Scrum, etc.). The second refers to *empirical applications*.

At the methodological level, Middleton (2004) argued that the essence of lean software development is *stockless production*, where work in progress (i.e. paper specifications and unfinished programs) is minimized so that production problems are revealed. By keeping work in progress under control, code errors can be identified early in the development process, and hence undiscovered rework - the main cause of delays in software development – can be reduced. Petersen and Wohlin (2010) proposed a new method, called Software Process

Improvement through Lean Measurement (SPI-LEAM), that allows to assess the performance of the development process and take continuous actions to arrive at a leaner software development over time. Wang *et al.* (2012), studied 30 reports that applied lean approaches in agile software development and identified six types of lean applications that can bridge the shift from agile to lean software development. Pernstal *et al.* (2013) investigated the use of lean principles and practices in software development for large-scale industrial projects. The authors concluded that most studies focused on *waste elimination* and *creating flow* in the software development process, but there was a lack of results for principles and practices derived from the Lean Product Development literature.

In terms of applications, Middleton (2004) presented two case studies and concluded that lean practices can improve significantly the software development process by introducing straightforward practices, such as simple tally marks to *record errors*, *visual measures* of quality control, and *moving the responsibility* for measuring quality from the manager to the workers. He also identified barriers, in improving the software process, including recruiting policies, organizational structure, and communication. Middleton *et al.* (2005) discussed a case of full adoption of lean by a software company. The solution involved a whole set of LM concepts, including: *standardized procedures* (e.g. file storage, names, locations, work space), *eliminating rework*, *balancing loads*, *minimizing inventory* (breaking major parts of the product into *stories* made up of 3-5 *features*, equivalent to 3-5 units of work that should be completed in 2-5 days). As far as the results achieved, it was estimated that there was a 25% productivity gain over the two years implementation period.

Staats and Upton (2011) and Staats *et al.* (2011) investigated the applicability of LM concepts in a software company and found that even in non-repetitive environments, lean practices may be applicable and can yield positive results. Some of the characteristics of the approach included: *iterative* development (instead of the waterfall methodology), *design structure matrix* for scheduling and sequencing tasks, *visual control board* for monitoring progress and discussing issues daily, *automatically created documents* (using Java documents) for detailed design documentation, *coding standards* in integrated development in order to automatically test and detect code defects, *daily builds* with pre-specified test cases. The benefits observed included 50% of cost reduction, as well as reduction in inventory, delivery time, and productivity. Malladi *et al.* (2011) studied the implementation of LM concepts in a leading software company. The authors identified a set of best practices in lean methodology for addressing *defect prevention*, *buffer management*, *resource optimization*, *delays* due to internal and external dependencies, *process overheads* and *team management*.

Finally, in IT areas besides software development, Holden and Hackbart (2012) investigated the application of a rapid improvement event (RIE), a participatory, weeklong, problem-solving session (similar to the Kaizen and the Plan-Do-Study-Act events) to improve the provision of technical support services. This led to the reorganization of the IT support work structure from *disconnected silos* or groups to *cross-functional* teams. The results of the change indicated that the main objective measure *first call resolution* was considerably improved from 52% to 75%. Lee *et al.* (2008) mentioned the case of Fujitsu Services, an international IT services company that managed to reduce repeated complaint calls by 80% in 18 months by applying lean consumption principles.

Overall, most researchers agree that LM concepts fit in IT and software development process and provide a number of successful implementations. However, similar to other sectors, the lack of systematic documentation and quantification of the findings do not allow generalizations of the positive impact or best approaches and of the effort required to implement lean in IT environment.

2.4.1.6 Government and public services

LM concepts have been applied to various activities of the public sector, some of which are discussed in other Sections of this Chapter. These include, *healthcare* (Esain *et al.*, 2005; Radnor and Walley, 2008; Radnor *et al.*, 2012; Burgess and Radnor, 2013), *education* (Comm and Mathaisel, 2005), *central* and *local* government operations (Seddon, 2005; Radnor, 2010), *military* (Murman, *et al.*, 2002; Agripino *et al.*, 2002; Bateman *et al.*, 2014) and other public organizations such as *policing* (Barton, 2013; Antony *et al.*, 2017). The most important reason for implementing LM concepts in public services include the significant budget pressures that require efficiencies, while maintaining the quality of service to the public (Antony *et al.*, 2017).

The related literature has investigated the extent that LM concepts are suitable for public service organization, given the differences between private and public organizations, such as *working environment*, *organizational goals*, *organizational structures* and *values* (Boyne, 2002). The majority of studies concluded that lean is applicable to the public sector, but certain adjustments are required (Radnor *et al.*, 2006; Radnor and Boaden, 2008). However, as pointed by Seddon *et al.* (2011), these adjustments are not clearly defined. Furthermore, the majority of improvements refer to small-scale and local initiatives and involve the application of *kaizen* events (i.e. rapid improvement events) and *value stream mapping* (Radnor and Osborne, 2013). These practices tend to be more focused on short-term outcomes rather than a clear long-term improvement strategy, a necessary condition to achieve longer-term sustainable impact (Spear, 2005; Radnor and Walley, 2008).

In terms of *impact* on performance, similarly with other service sectors, there is no systematic quantification of the benefits in the literature. Most references relate to quality, cost and time as well as intangibles such as increased customer and employee satisfaction (Radnor and Boaden, 2008; Radnor *et al.*, 2006; Barton, 2013; Antony *et al.*, 2017). The limited scale of the related improvements led several authors to question the impact that lean methodologies could bring to public services (Radnor *et al.*, 2012). In other cases, the application of Lean has been found to be detrimental to staff and to the quality of service, as staff perceived lean counterproductive due to lack of autonomy and discretion, increased workload and lack of support (Carter *et al.*, 2011). It is noted that due to the lack of systematic reviews, current findings do not allow generalizations on the positive impact and best approaches to implement LS in public sector organizations.

2.4.1.7 Education

Driven by pressure to reduce costs, several researchers investigated the possible extent of applying LM concept to education. The research focus has been primarily on *public and private higher education institutions* (i.e. universities), while LM concepts have been applied mostly to the *operations* and *administrative* units of such institutions (Comm and Mathaisel, 2005). Surprisingly, we have found also references focusing on the design and delivery of *teaching and research* (Emiliani, 2004; Tatikonda, 2007). For example, Tatikonda (2007) argues that waste in education occurs when time and effort are invested while students do not gain any new knowledge or skill. Typical examples of wastes include: *overproduction*, i.e. teaching topics already taught in other courses or that have become obsolete; *over-processing*, i.e. excessive review of prerequisite course materials, unnecessary and redundant introductions; *waiting*, i.e. for unprepared students to catch up, for students to get their grades, etc.

In terms of *lean tools and methods*, a variety of tools have been applied in past studies, with TQM practices being the most cited ones (Owlia and Aspinwall, 1997; Van der Wiele, 1995; Spanbauer, 1995; Dahlgaard and Ostergaard, 2000). Comm and Mathaisel (2005) investigated the application of lean and sustainable initiatives (using an appropriate survey questionnaire) in 13 private and 5 public universities. Maguad (2007) argued that several lean tools can be applied in higher education such as: *5Ss*, *mistake-proofing*, *value stream mapping*, *quick change over*, *self-inspection*, *total productive maintenance* (where equipment is involved) *and kaizen* events. Emiliani (2004) investigated the applicability of *continuous improvement* to solve MBA course problems, *5Ss* to simplify and sequence course content, *JIT* for returning graded papers on time, *load balancing* to balance effort throughout the semester, *respect for people* to manage expectations and incorporate students' feedback, *standard work* to syllabus formats and course content, and *visual control* to highlight most common mistakes made in the past, etc. One of the few attempts to use LM concepts in the core of educational services, that is, in the body of knowledge, is the work of Tatikonda (2007). In particular, the author suggested implementing *cause and effect diagrams* to identify major causes of poor-quality education, *quality function deployment* for designing critical attributes for academic courses (in particular accounting), *cellular layout* for grouping topics with a common underlying theme in families and streamlining the course delivery, and *balance scorecard metrics* to assess students' learning.

In terms of *impact* on performance, there is no detailed quantification of the benefits achieved, but mostly anecdotal references. In any case, the findings from previous studies suggest that LM practices can have a significant impact in reducing costs and improve operational and overall effectiveness of both administrative and educational academic activities (Emiliani, 2004, 2005; Comm and Mathaisel, 2005; Maguad, 2007; Tatikonda, 2007; Hines and Lethbridge, 2008). Finally, Thomas *et al.* (2015), emphasized the importance of taking a long-term strategic approach in adopting LM concepts, instead of approaching it as a cost-cutting exercise to achieve quick savings.

2.4.1.8 Other service industries

Up to this point we have reviewed applications of LM concepts in selected service industries. In reviewing past lean studies, there are a few empirical applications in other industries which are discussed below.

In *hospitality and tourism*, there are a few empirical cases indicating that LM concepts may support the hospitality industry reduce their operating costs, improve response time and quality of service delivered to clients. For example, Barlow (2002) investigated the application of *JIT* practices in purchasing and inventory management of two hotel groups. Cuatrecasas (2004) used LM concepts to optimize the check-out service of a hotel. Vlachos and Bogdanovic (2012) surveyed small and medium hotels in 19 European Union (EU) member states to investigate the level of adoption of lean principles. Rauch *et al.* (2016) presented examples of lean methods applied in the hospitality sector.

In the *telecommunication industry*, Robertson and Jones (1999) presented some initial ideas for applying agile manufacturing concepts to telecommunications, namely in call center receiving orders/ questions, and in field engineering responsible for network connections (e.g. proactive maintenance). Arbos (2002) proposed a methodology for implementing lean in a services telecommunication production system, and certain actions to be assumed in order to mediate excessive variability in the system when it is excessive. Akkermans and Vos (2003) investigated the demand drivers in a telecommunications company and found that by implementing quality improvements across several departments of the company, demand variation can be reduced significantly.

The applicability of LM concepts has been investigated to a lesser degree in *administrative and other corporate functions*. The basic idea of lean in non-repetitive environments is to reduce the time spent on non-value-added activities, so that professionals can focus on more complex-intellectual tasks. Kennedy and Widener (2008) implemented lean practices in the accounting function of a manufacturing company. The practices employed include streamlining of transactions processes, use of actual instead of standard costs, a kanban system to initiate purchasing, and a new performance management system. Reinertsen and Shaeffer (2005) investigated the applicability of lean to the Research and Development function. The authors concluded that the concept of small lots combined with the concept of pull could reduce queues and cycle time. Higgins (2007) investigated the application of LM in the Human Resources (HR) function of a mining company. Following the rollout of lean in the HR department, the organization realized more than 15% cost savings from a global annual budget in excess of £40 million.

2.4.2 Aspects of lean implementation

The implementation of lean has been a significant topic in the LM literature. Most studies include empirical applications - described through case studies (an overview has already been provided in Section 2.4.1) - and the associated *implementation frameworks* (for a complete literature review refer to Anvari *et al.*, 2011; Mostafa *et al.*, 2013; Marodin and Saurin, 2013; and Rafique *et al.*, 2017). Given the lack of a commonly accepted implementation approach (Rafique, *et al.* 2017), we examine selected aspects of implementation such as the *scope*, the various *stages* of the implementation roadmap and the *sequence* of implementing lean practices. We use references primarily from the service literature and in case of limited sources we complement the review with manufacturing sources, since a lot of these concepts were originated in manufacturing.

2.4.2.1 Scope of implementation

Scope refers to the *type and magnitude* of the changes required for an organization to become lean. As discussed earlier (Section 2.2.3), LM takes a *holistic* view and requires significant changes ranging from product design, to manufacturing and to close supplier relationships (Jina *et al.*, 1997). These practices have interrelations and dependencies that cannot be ignored and, consequently, they should not be implemented in isolation (Hayes *et al.*, 1988).

However, as we noticed in the previous chapter, the scope of lean implementation both in services and in manufacturing has focused more on certain units, processes, or lean practices and less on company-wide transformations. Furthermore, in several cases, lean implementation has been seen as a cost reduction program, as opposed to a continuous pursue of superior performance over the long run. This is in contrast with what most lean proponents suggest; for example, Ahlstrom (1998) argues that "*LM does not have a defined end point, but it points to the direction in which a company should continually move*". Therefore, it is important to link any lean implementation effort with the long term vision and strategic objectives of the company.

Mostafa *et al.* (2013) investigated 28 lean implementation initiatives in manufacturing and classified them in the following categories: *roadmap*, *implementation framework*, *descriptive* and *assessment checklist*. The authors found the initiatives in the roadmap and implementation framework categories to be the most successful ones, since they focus both on human and technical factors, providing benefits within a short time and continuous improvement in the long run. Similarly, in services and in particular in healthcare, Burgess and Radnor (2013) classified lean implementations as *tentative*, *productive ward only*, *few projects*, *program* or *systemic*. The authors proposed the full implementation, or *systemic*, approach as the most suitable one to achieve full lean potential. This would embed lean in the organization's long term strategic vision aiming at achieving sustainable change over short gain through cost savings.

2.4.2.2 Stages of implementation roadmap

The *stages* of implementation roadmap refer to the distinct phases in the process of implementing lean in an organization. We present three notable references that have dealt with this topic in the next paragraphs. The first (*Transition-To-Lean Roadmap*), is one of the first attempts to define a lean roadmap not only for the production function but for the entire enterprise. The second (*Five-phase dynamic roadmap*), is a typical lean implementation approach for a production environment. The third (*Lean service implementation roadmap*), is one of the few transformation approaches documented in the service literature. We close this Section by discussing similarities and differences across approaches.

The *Transition-To-Lean Roadmap* by MIT (Crabill *et al.*, 2000) proposes a sequence that is based on precedence. It concerns internal functions (i.e. engineering, human resources, commercial) and external entities (i.e. suppliers and customers) that are necessary to implement lean. It is based on the lean principles of Womack and Jones and comprises eight phases:

- *Phase 0 - Adopt Lean Paradigm:* It aims to set the transformation vision, to train and get senior management buy-in and commitment.
- *Phase 1 – Prepare:* It aims to define the strategy and the support structure required for lean transformation (e.g. establish lean implementation teams, plan, training, and target objectives)
- *Phase 2 - Define Value:* It aims to define the customer, value of the product and initial implementation scope, which can range from a very narrow area such as a specific family of parts, or a process to a more ambitious, and risky, scope such as a large or complex assembly or an entire manufacturing facility or site
- *Phase 3 - Identify Value Stream:* It aims to map a value stream that shows the entire information and production process as a system with measures of value added and waste for each process
- *Phase 4 - Design Production System:* It aims to define the future state of the production system, including elements such as future value stream map, takt time requirements, make/ buy decisions, suppliers' integration and visual controls.
- *Phase 5 - Implement Flow*. In this phase individual cells are established in the production system to localize material flow within those cells. This phase also includes various practices such as standardization, quality control, cross training, setup reduction, visual control and predictive maintenance
- *Phase 6 - Implement Total System Pull*. It aims to link individual cells within the production system and suppliers through the appropriate pull mechanism. This

phase also includes practices such as selection of the control mechanism, single item flow, level and balance of the production flow and linking with suppliers

- *Phase 7 - Strive for Perfection*. Finally, this phase sets the basis for continuous improvement and learning from the journey to date. The various Lean techniques and tools implemented in earlier phases are reviewed and refined (this phase can take place at concurrently with Phases 2 through 6)

Anvari *et al.* (2011) reviewed several implementation approaches and synthesized a *Five-phase dynamic or "lean" roadmap*. The five phases are:

- *Phase 0- Initial investigation* is used to assess three readiness questions including whether there is an emerging need (e.g. crisis in sales, falling profits, etc.), if there is commitment from management, and if there is "lean" knowledge and resources
- *Phase 1- Preparation:* It includes activities for strategic planning, lean resources and capabilities, familiarization with the organizational structure, objectives, setting, product family focus, procedures, metrics, and determining the managers of VSM.
- *Phase 2- Focus on specified pilot*. A family product is selected as a pilot to implement lean, followed by a five-step logical sequence for achieving (manufacturing) excellence during the pilot phase (discussed in the next Section)
- *Phase 3- Expand to whole system:* It suggests that the lean methodology should be applied to all product families following the subsequent five phases *VSM, continuous flow, stability, flexibility, and pulling*. The approach can then be rolled out to the office functions and to organizations outside the enterprise (suppliers and customers)
- The last phase, *Phase 4- Perfection*, aims to measure performance and lean maturity using the lean enterprise self-assessment tool (LESAT), and to focus on continuous improvement.

Allway and Corbett (2002) developed an implementation approach for services, the *Lean service implementation roadmap*, following an application in the financial services industry. The approach comprises five phases:

- *Phase One: Assessment of the Current State.* It aims at assessing a selected area of an organization in terms of operational excellence and identify opportunities for waste reduction and improvement. Typical activities of the diagnostic include mapping process flows for the selected area, collecting existing measures, and assessing the overall process effectiveness.

- *Phase Two: Determining the Target State*. It aims at defining a target state for the selected area that is linked with the business strategy and with specific business objectives. Typical activities include the development of the vision, the related key performance indicators for each process and function and a high-level action plan to be communicated to the entire organization.
- *Phase Three: Stabilizing the Operations*. It aims at identifying the main root causes of existing inefficiencies that drive instability in existing processes. Once the root causes are identified, then solutions are developed and put in practice to evaluate progress and impact on performance.
- *Phase Four: Optimizing the Opportunities.* Once operations are stabilized several initiatives can be launched to optimize physical design and flow, such as redesigning the office layout, optimizing continuous flow of materials, people, and information, etc.
- *Phase Five: Institutionalizing the Lean Approach*. It aims at institutionalizing lean in the organization, through several activities such as leveraging lessons learned from previous experience and redefining the transformation approach, conduct continuous training to cover existing gaps, planning for the next areas to be transformed, tracking progress towards objectives and finally communicating the progress at all levels in the organization.

Overall, most implementation frameworks include key phases, e.g. the preparation phase includes activities such as management commitment, training in lean and building of the implementation team. This phase is typically followed by a pilot in a certain value stream by analyzing and baselining the current state, defining the future state, implementing improvements and sustaining the improved state. Further efforts are then planned to implement the pilot in other areas and institutionalize lean across the organization (D'Andreamatteo *et al*., 2015).

2.4.2.3 Sequence of implementation

The *sequence* of implementation is considered an important component of a successful lean implementation. It refers to the *time and order* to implement the lean initiatives within a pilot unit, as well as within a network of units (e.g. branches in financial services), especially if they are widely dispersed across various locations. In the next paragraphs, we examine the various approaches regarding the sequence of implementing lean changes within a pilot project (product family, plant or branch).

Once the preparation is complete, most authors and practitioners suggest a lean pilot project to be carried out to create a prototype for lean implementation. Various approaches have been proposed to define the "ideal" starting area. For example, Womack and Jones (2003) suggest that the implementation process should start with the most problematic subunit within the organization. Braglia *et al.* (2006) propose to start from high-volume products (or products defined by a combination between production volumes and revenues), since these products are responsible for the largest part of non-value-added costs (e.g. material handling, WIP, queuing, etc.) and can boost the overall performance of a production system.

In cases in which a great number of products and production flows are not deterministic (e.g. in a job-shop environment), the authors (Braglia *et al.*, 2006) propose the implementation of lean (and in particular value stream mapping) through a seven-step process. In the first two steps (i.e. select a product family and identify machine sharing), the authors propose the selection of the highest production volume product family by grouping products into families using sophisticated clustering methods. In the third and fourth steps (i.e. identify the main value stream and map the critical path) the authors suggest mapping the *critical production path*, by selecting the longer production path as defined by the Temporized Bill of Material (TBOM). In the next steps (i.e. identify and analyze wastes and map the future state), the focus shifts to identifying improvement opportunities and solutions for the critical/sub-critical path. The improvement process continues until the critical value stream has been optimized and a new path becomes critical. Finally, in the last step (i.e. identify the new critical path and iterate the process), the same process is repeated until all potential paths have been improved.

Ahlstrom (1998) argue that lean production principles may be implemented in an ordered sequence. Installing a system of *zero defects* (i.e. quality improvement system) and *delayering* (i.e. reduction of hierarchical levels, responsibility and authority pushed down to the lowest levels, decentralization and integration of functions) should be the first steps in lean implementation. In addition to these steps, management needs to devote resources and time in parallel to three *core principles*: *waste elimination* (i.e. through set-up time reduction, preventive maintenance to reduce machine downtime, and manufacturing cells to reduce transportation distances), *multifunctional teams* (i.e. staffed by operators able to perform several tasks, if not all, in a cell), and *pull production scheduling* system (i.e. for reducing batch sizes and eventually inventories). The author also suggested a *vertical information system* (i.e. performance information for rapid decision making) and *team leaders* (i.e. taking the role of the advisor, coach and provider of support) as two additional *supporting principles* applied during the entire implementation period.

Hopp and Spearman (2004), following their theory on variability reduction (discussed in Section 2.2.3), proposed the implementation of lean through four phases: the *first* phase aiming to reduce direct (obvious or execution) waste, the *second* to switch inventory for capacity buffers (i.e. increase capacity since capacity is less expensive than inventory and in order to have more time to implement improvements), the *third* to reduce (undesired) variability and the *fourth* to reduce capacity (i.e. once undesired variability has been reduced, extra capacity buffer can be reduced as well). Phases three and four should be performed in a continuous basis aiming to remove sources of variability so that both inventory and capacity buffers could be reduced. The authors recommend against using a classic company-wide rollout of their concept. Instead, they proposed to teach at an appropriate level, the underlying practical but scientific methods to the teams working on production or inventory control processes (Pound *et al.*, 2014). They also suggest using existing lean or six sigma resources more efficiently by focusing them on identifying and eliminating sources of variability.

Anvari *et al.* (2011) proposed a five-step process to implement lean during a pilot lean project, with each step aiming to reach one of the following states: continuous flow, stability, flexibility and pooling. The starting point is a detailed description of the targeted *current and future value stream map (VSM).* The next step aims at *continuous flow*, which is typically achieved through flexible work systems (e.g. group technology and cellular manufacturing) and other techniques such as 5S, automatic guided vehicle and waste elimination. The next step aims at *stability*, which can be achieved by standard work (e.g. standard operating procedures), and other techniques aiming to improve quality (e.g. jidoka/autonomation, poka-yoke, self-control, and visual management) and machine breakdowns (e.g. total productive maintenance). The next step aims at *flexibility*, which can be achieved by cross-training, implementation of setup time reduction techniques (e.g. single minute exchange of dies) and by balancing workload (e.g. Heijunka/leveling). The final step aims at *pulling* and can be achieved through the Takt time, “one piece flow”, FIFO line and the supermarket concept.

The previous approaches, although different, entail some common characteristics. For example, mapping the current and future state of a value stream and identifying the improvement opportunities are the first steps in the majority of approaches. Aiming at continuous flow and stability and prioritizing the associated - easy to implement - initiatives seems to be the overarching sequencing approach (e.g. grouping product families into manufacturing cells to reduce unnecessary movements and space, and improving quality to reduce rework). While more complex activities, such as flexibility and pulling (e.g. cross-training and setup reduction) seem to follow. This is in line with the Hopp and Spearman (2004) approach, in which the less obvious sources of variability (e.g. due to product design and supplier involvement) are to be addressed at later stages.

The above concepts could be also relevant for service environments. Wei (2009) proposed similar LS process design principles including baselining the current state, error-proofing the process (and reducing loop-backs), enabling one-piece flow, standardization, and segmenting complexity of services. In addition to sequencing, another challenge in services (as well as in manufacturing) is how to implement a lean program in a network of units (service branches, plants, etc.) especially if they are widely dispersed in different locations.

Radnor (2010) described the implementation of lean in all HMRC (Her Majesty's Revenue and Customs) strategic processing sites in the UK. A number of dedicated local Lean experts were based in local offices; these were supported by dedicated central Lean experts who rotated over three-month periods between sites. In addition, the HMRC staff were supported by external consultants who worked with the central and local Lean experts in order to transfer lessons learned and best practices.

Frei (2006) suggested the Wells Fargo "*challenger-champion*" model to overcome some common mistakes in pilots (i.e. setting realistic conditions so that a comparison between sampled units is objective). According to this model, for every new initiative, the company selects a baseline sample to test the new initiative (the challenger sample) and a similar, test sample (the champion sample). In this way the company tracks differences in behavior between the two samples, helping them to determine the improvements.

Overall, implementing lean in a network of sites has been acknowledged as an interesting research topic for further investigation (Netland and Ferdows, 2016). To the authors' experience the available options include a linear, sequential implementation approach, a parallel or a combination of the two. The urgency (i.e. speed) of implementing the changes, versus the investment and time required to acquire the resources to implement the transformation are critical factors that need to be balanced and considered.

2.4.3 Barriers and critical success factors of lean implementation

To reap all the benefits from LM, organizations need to make a number of changes, ranging from improving operating procedures and service systems to accepting LM as an organizational philosophy and changing the organizational culture (Yasin *et al.*, 2003). In the current Section, we build on the earlier discussion (Section 2.2.2) regarding the barriers and the critical success factors for lean implementation. In Table 2.7, we distinguish the *technical* and *human related* barriers, we list their root-causes and identify potential solutions based on past literature. We do not examine the relationships among barriers - a topic not investigated thoroughly in the literature (Mantha and Rane, 2014). However, linking the barriers with their root causes may serve as a useful guide for assuming appropriate actions during lean implementation.

Table 2.7: Barriers and critical success factors of lean implementation

Category	Barrier	Potential Root Causes (non-exhaustive)	Source
Human (soft) related barriers	*Senior Management's limited understanding, support and commitment*	Misunderstanding and/or insufficient understanding regarding the concepts and purposes of lean, leading to low commitment and a narrow perspective that views lean as a set of tools, techniques and practices	(1), (2), (3), (5)
		Limitations in (strong/ good) leadership skills and visionary leadership	(3), (4), (5)
		Lack of clear communication (between management and employees)	(2), (3), (4)
	Employees' resistance and/or lack of engagement	Cultural issues, differences and company culture	(1)-(5)
		Unionized employees resisting to certain lean practices (e.g. cross-functional work) or to downsizing	(1), (4)
		Lack of empowerment of employees, including insufficient team autonomy	(3), (4)
		Lack of formal training for workers and managers	(1)-(5)
		Incompatibility of lean with the company recognition, rewards or incentives systems	(4), (5)
		Lack of cooperation and of mutual trust between management and employees (due to job security and threat to established ways of working)	(4), (5)
Technical (hard) related barriers	*Lack or insufficient resource availability*	Too much time to implement and to realize the benefits from lean, and/or insufficient management time	(1), (3), (4)
		Lack or insufficient resources to invest or high investments/costs or financial constraints for internal/ external funding	(1), (2), (3), (4)
		Lack or insufficient skills/expertise to implement lean across all roles, i.e. employees, managers, senior managers and consultants/facilitators	(1), (3), (4)
	Inappropriate scope and technical limitations	Lack of process thinking and process ownership	(3)
		Poorly defined focus that causes or shifts problems to other parts of the organization and does not address cross-functional conflicts or required structural interventions (e.g. changing product design)	(4), (5)

Category	Barrier	Potential Root Causes (non-exhaustive)	Source
		Problems with data availability, high process variability and layout configuration	(3), (4), (5)
	Implementation challenges	Misalignment between lean, strategic objectives and customer orientation	(3)
		Absence of a sound roadmap to guide implementation, including how to get started and how to select and prioritize initiatives	(3), (4), (5)
		Poor delivery driven by wrong selection of Lean/Six Sigma tools or blindly applying tools without understanding their intent	(3)
		Poor delivery driven by limited organizational capabilities and ineffective project management	(3)
		Lack of or insufficient performance measurement system for continuous evaluation on lean	(2), (3), (5)
	Suppliers and customers lack of support and cooperation	Quality problems with supplies	(4)
		Lack of influence over suppliers and/or customers or lack of involvement of suppliers and/or customers in actual implementation	(3), (4)
		Lack of supplier collaboration or lack of mutually beneficial strategic partnership with suppliers and customers	(3), (4)
		Lack of information sharing/communication with suppliers	(4)
		Lack of logistical support	(4)

(1) Sanjay (2012), (2) Nordin *et al.* (2012), (3) Albliwi *et al.* (2014), (4) Jadhav *et al.* (2014), (5) D'Andreamatteo *et al.* (2015)

In terms of human related barriers, the lack of support from senior management and employee resistance have been the two most cited barriers in the past LM implementation literature. In particular, senior management is considered to be the most important barrier but also the most critical success factor. For instance, early studies of JIT implementations (see for example Nathan and Trinkaus, 1996) suggest that JIT projects initiated by top management are significantly more successful than projects initiated by middle level managers or individual departments. More recent studies lead to similar observations. For example, Hallam *et al.* (2018) reviewed 109 peer-reviewed papers of companies that implemented lean and found that lean transformation yields mixed results unless strategic actions are taken by senior management, such as knowledge management, human resource and business growth.

Senior management can influence a lean transformation in a number of ways (Nordin *et al.*, 2012). It is responsible for funding resources and resolving cross-functional conflicts that may derail implementation. Insufficient understanding of LM can lead senior managers to a narrow view that emphasizes cost and throughput over quality, or to limited applications of lean tools that do not undress fundamental change. Moreover, LM needs strong leadership to provide the vision and strategy for change, to motivate and most importantly to establish role models for expected behaviors. Communication is also regarded as both a critical success factor and potential barrier if it is inconsistent and unclear (Karlsson and Ahlstrom, 1996). It is suggested that communication should focus on the strategy and vision, the criteria for success, as well as the expectations from managers and employees during/ after lean implementation (Nordin *et al.*, 2012).

Employees' resistance and lack of engagement is another important human related barrier for successful LM implementation. This can be attributed to a number of reasons, including cultural differences, driven primarily by the lack of training and education on lean principles and tools (Nordin *et al.*, 2012), the fear of downsizing, driven by the belief that lean is a cost reduction program (Mantha and Rane, 2014), as well as resistance towards standardization, driven by the belief that "standard work" is associated with lack of responsiveness, autonomy and creativity (Randor, 2010). In particular, the concept of standard work, as stated by Randor (2010): "*is perceived as not suitable for service environments, where it may be important to respond to demand in a number of ways*".

The literature proposes a number of actions to address these barriers, such as: providing the appropriate training; providing rewards and incentives for every level in the organization (D'Andreamatteo *et al.*, 2015); involving employees in the development of standard work processes and new ideas (Randor, 2010); modifying lean terminology and adjusting it to fit more naturally the service environment, as well as fostering the purpose, rather than the plain use of lean tools (Duclos *et al.*, 1995; Randor, 2010); taking a long-term view of continuous improvement by communicating its importance and by setting relevant key performance indicators that measure progress (Randor, 2010; D'Andreamatteo *et al.*, 2015). Finally, breaking down barriers between functional areas and enabling easier and faster communication, collaboration and coordination, has been emphasized early on as more critical in services than in manufacturing (Mehra and Inman, 1990).

From the technical standpoint, the time and resources to implement changes (including time, expertise, and financial resources) is a main barrier of LM implementation. This is more pronounced in small and medium enterprises (SMEs), which lack adequate funds to recruit experienced employees or external consultants. The role of the latter has been emphasized in past LM literature. In addition to motivating employees, consultants are responsible for educating and to a certain extent institutionalizing LM in organizations. Furthermore, lean requires substantial changes, making it almost impossible for an organization to attempt these changes without help from knowledgeable outside experts (Nathan and Trinkaus, 1996).

However, past literature suggests some attention points when using external consultants. First, the transformation, especially in the long-run, should not depend entirely on external experts. The latter need to transfer knowledge, but the organization needs to develop its own mindset, commitment and capabilities to continue the lean transformation (Bamber and Dale, 2000). Second, management consultants need to provide experienced staff (instead of solely young generalists) who are able to coach and mentor internal employees (instead of only teaching lean tools and techniques) (Holmemo, Rolfsen, and Ingvaldsen, 2018). Third, when companies engage consultants in the early stages of a transformation, it is important to involve them not only on easy problems but in more complex ones and at the same time utilize them in developing deep problem-solving capabilities of employees and managers. (Chakravorty and Hales, 2012).

Another important barrier relates to the scope of transformation. We discussed in the previous Section that the scope of transformation is often limited to certain units, processes, or lean practices. Most importantly, the decision to implement Lean often precedes the identification of problems which poses the risk of not addressing the real problems in the organization (Langstrand and Drotz, 2016). Other technical limitations in services include the high process variability and problems in defining waste (D'Andreamatteo *et al.*, 2015), as well as challenges in data collection and analysis. The latter is considered by many authors as the most common failure factor in the service sector, as data are not always easily available, and significant time and effort needs to be devoted to collect them (Albliwi *et al.*, 2014).

Other implementation challenges include the misalignment between lean, strategic objectives and customer requirements including demand, absence of a sound roadmap, poor execution and lack of or insufficient performance measurement system for continuous evaluation on lean. These elements should be aligned, starting from a thorough understanding of the needs of different types of customers (as they evolve over time), setting clear strategies and improvement projects for meeting those needs, and having a relevant and robust measurement system (Albliwi *et al.*, 2014). For example, in a hospital setting, it is critical to link improvements to patient safety, patient satisfaction, and to the business-economic performance of the hospital (D'Andreamatteo *et al.*, 2015).

Finally, lack of support and cooperation from suppliers and customers is a key barrier. Past research (Nathan and Trinkaus, 1996) suggests that both in manufacturing and services, involving customers and suppliers is significant for the success of implementation. In services, involving customers might be even more critical than involving suppliers, since customers have a dual role acting also as suppliers. Service organizations should engage with customers to understand better their needs and effectively disseminating them in the operating service system and the product/ service offering. They should also seek customer involvement in designing and developing new products and services.

2.5 Sustainability of lean manufacturing concepts in services

In the previous Section we reviewed the transferability of lean in services, and overviewed implementation cases and approaches across service sectors, as well as the challenges to be overcome during implementation. In this Section we examine the *sustainability* of lean in services and clarify *what* constitutes *sustainability* in the context of *continuous improvement*, as well as *how* continuous improvement can be assessed and managed. Finally, we examine *factors and challenges* to overcome (after the implementation) and sustain continuous improvement.

2.5.1 Definition and perspectives of continuous improvement

Following failed attempts across sectors to sustain the practices and benefits of LM (Womack and Jones, 1996; D'Andreamatteo *et al.*, 2015), sustainability gained the attention of researches and became a separate theme in the LM literature. By sustainability in the context of LM[8] we refer to *continuous improvement* (CI); that is, the ability of organizations to *sustain results* (first-order sustainability) *and continuously improve* (second-order sustainability) over time (Poksinska and Swartling, 2018). Given the broadness of the topic, in the current Section we focus on the definition and main perspectives around CI (*static and dynamic*), while in the next two Sections we focus on the approaches to measure and maintain CI respectivelly.

The concept of CI, or *kaizen* in Japanese (i.e. improvement for the better), has been part of the various improvement methodologies (JIT, TQM, LM), used to describe the *principle of improvement*. Early process improvement influencers incorporated the CI concept into their philosophy and tools. Indicative examples include (Choi, 1995): Deming's *plan-do-check-act* cycle (a.k.a. Shewhart cycle) of continuous improvement; Taguchi's *quality loss function* and the focus on achieving the target value; Shingo's attribution to CI of the success of Japanese manufacturing; Womack and Jones' (1996) fifth lean principle of continuous pursue of *purfection*. In more generic terms, CI has been used to describe a *culture* of sustained

[8] Sustainability in general has been associated with the need of businesses to address and manage the economic, social and environmental impacts of their activities (Elkington, 1998)

improvement targeting waste elimination (Bhuiyan and Baghel, 2005), as well as *a systematic effort* to actively and repeatedly making process improvements (Anand *et al.*, 2009).

We distinguish two main perspectives around CI: *static* and *dynamic*. According to the static view, CI is the result of defined *characteristics* and *practices*.

The *characteristics* of successful organizations in CI typically include (Showalter and Mulholland, 1992; Choi, 1995; Bhuiyan and Baghel, 2005): a *culture* that considers change as the norm and has the discipline to establish standard change routines; *high involvement* of employees, with improvements coming from the collective intelligence of employees with minimum interference from management; *team work* and *cross-functional collaboration* as a way of working to implement change; *wide range* of changes including both *incremental* and *radical*. The former are changes with low risk, disruption and capital investments, resulting from the accumulation of small, frequent modifications to ongoing processes, while the latter are changes that take place typically as a result of an innovative idea or new technology.

The *practices* that support CI include (Table A.1 of Appendix A): a) *employee cooperation and participation* in improvement (kaizen) events using CI tools (such as value-stream-mapping, visual-management, etc.) and famous quality techniques (such as quality-at-source, quality-circles, etc.), and b) *product development* concepts and tools (such as modular-design, concurrent-engineering, etc.). Although product development is a separate theme in the LM literature, we have included it under the CI umbrella, since it contributes to the organization's growth and prosperity. Under this perspective, launching new products (or improved versions of existing ones), as well as efforts to improve the process of product development should be considered as part of CI. Finally, *human resource practices* are considered part of CI as well, since they are important enablers, necessary to institutionalize CI in an organization. For example, to build *lean capabilities* (such as self-directed-teams, flexible-workforce, employee involvement, etc.), the respective HR policies (for training, compensation and rewards, job-design, etc.) need to be adjusted (Jorgensen *et al.*, 2007; Anand *et al.*, 2009).

The *dynamic* perspective suggests that CI is the result of an organization's *dynamic capabilities* instead of a set of static routines that can be imitated by competitors. We briefly discuss two predominant dynamic concepts of CI in the next paragraphs and elaborate them further in Section 2.5.3. The first concept refers to an organization's ability to manage and mitigate the *interactions and unintended consequences of the improvement process* to other processes and functions in the organization, a concept known as the *improvement paradox*

(Sterman *et al.*, 1997; Keating *et al.*, 1999; Repenning and Sterman, 2001). According to this concept, improvement programs may adversely impact financial performance despite their success in improving operational performance. Furthermore, managing improvement programs as a pure cost reduction exercise might put the sustainability aspect of an organization at risk, leading to what is referred to as *organizational anorexia* (Radnor and Boaden, 2004; Gupta *et al.*, 2016). Successful improvement programs, therefore, require from managers to anticipate the wide-ranging effects of improvement and maintain a balance between the short and long-run (Keating *et al.*, 1999).

The second refers to an organization's ability to adapt and respond to changes in the environment, a concept also known as the *Red Queen Effect*[9]. According to this concept, sustaining a competitive advantage is not just about achieving high performance, but it is about consistently improving at a faster pace or greater magnitude than the competitors (Su *et al.*, 2014). This might explain why many improvement programmes, despite having all the essential elements and invested resources, they were eventually abandoned after a few years (Chakravorty and Hales, 2016).

2.5.2 Sustainability assessment of lean and continuous improvement

In addition to the CI topics discussed in the previous Section, there is a literature stream dedicated to the usage of assement tools to measure the progress of lean transformations and the sustainability of CI (Malmbrandt and Ahlstrom, 2013). These assemment tools typically inlcude *frameworks* for *assessing lean capabilities* towards a state of *maturity* necessary to achieve long-term sustainability of lean (Jorgensen *et al.*, 2007) and/or for *quantifying the level of leanness* through individual or integrated indicators (Wong *et al.*, 2014). The tools are supported by guidelines as to *what needs to be assessed* (e.g. practices, enablers, outcomes) and the *way to assess it* (e.g. quantitative vs. qualtitative indices, maturity scales, self vs. expert assessment). We briefly review in the next paragraphs the literature as it evolved in manufacturing and later discuss the adaptations made in services.

Most common approaches to measure the *leanness* of organizations for sustainability purposes include *qualitative*, *quantitative* and *mixed* approaches (for a complete literature

[9] This concept was inspired by a dialogue that the Red Queen and Alice had in the Looking Glass, the sequel to Alice in Wonderland. Alice was running as fast as she could, but she realized that she was not getting anywhere. The Red Queen responded: "*Here, you see, it takes all the running you can do to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!*" (Su *et al.*, 2014; Su, 2016; Chakravorty and Hales, 2016)

review refer to Narayanamurthy and Gurumurthy, 2016). *Qualitative* approaches include assessment surveys of principles and practices of lean adoption and sustainability. The most popular tool is the Lean Enterprise Self-Assessment Tool (LESAT) developed by the Lean Aerospace Initiative at MIT (2001). It contains 54 lean practices organized into three assessment sections: *Lean Transformation/Leadership*, i.e. the processes and leadership attributes supporting lean transformation and sustainability; *Life Cycle Processes*, i.e. the processes responsible for the product from conception through post delivery support; and *Enabling Infrastructure*, i.e. the processes that provide and manage the resources enabling enterprise operations. Each practice is self-assessed againt five capability levels ranging from least capable to world-class (Nightingale and Mize, 2002). Other assessment surveys, such as the *Lean Capability Model* (Jorgensen *et al.*, 2007), use more generalized levels of lean maturity starting from *sporadic optimization efforts* i.e. efforts not linked to an overall strategy or philosophy and/or isolated to specific units, to *integrated lean in the extended enterprise*, i.e. a state where lean and CI are part of the daily work, aligned with HR practices and with the strategic objectives across the enterprize. A typical weakness of these tools is that they do not link the implementation degree of lean practices with the impact on financial and operational performance (Jorgensen *et al.*, 2007).

The second category includes *quantitative approaches* using individual measures or integrated indicators to measure the level of leanness. A typical example of the later is the *integrated leaness index* (Wong *et al.*, 2014) which measures the overall leanness level across *all stages* (i.e. functions) and *aspects* of performance (e.g. lead time, quality). This has the advantage of identifying interrelations between measures and hence estimate more accurately the leanness level of an organization. It can also help managers understand the interdependencies between functions and hence manage better the interfaces/conflicts among them (Wong *et al.*, 2014).

Finally, there are *mixed approaches* combining both quantitative measures and qualitative practices. Such an example is the *fuzzy-logic leanness measure* (Bayou and de Korvin, 2008), which measures leanness as a single score using both quantitative measures (e.g. inventory) and three lean practices: JIT, Kaizen, and TQM. Other similar approaches include the *leanness assessment tool* (LAT) (Pakdil and Leonard, 2014) that measures leanness using eight quantitative performance dimensions: *time effectiveness, quality, process, cost, human resources, delivery, customer and inventory* and five qualitative performance dimensions:

quality, process, customer, human resources and delivery with 51 evaluation items. The tool helps managers visualize improvement areas for a successful lean implementation.

Overall, the latest trends for these approaches include: the *shift* from measuring leanness at an enterprise-level from a process level; better *linking the impact of lean practices* (especially human resource-realtaed) on financial and operational performance, and *benchmarking the degree of leanness* with other organizations (Narayanamurthy and Gurumurthy, 2016).

In services, past research suggests limited examples of CI assessment approaches compared to manufacturing. Indicatively, there are references that use typical lean measures such as lead time reduction (Apte and Goh, 2004; Cuatrecasas, 2004). However, these efforts were not indended to assess the adoption of lean and CI practices (Malmbrandt and Ahlstrom, 2013). There are also references focusing on the adaptation of manufacturing assessment tools in services. Examples include a) the adaptation of LESAT to the software development process and tits validation to the R&D department of Ericsson in Finland (Karvonen *et al.*, 2012) and b) the adaptation of a measurement instrument to assess quality practices in selected large public hospitals in China (Xiong *et al.*, 2015).

Overall, the most relevant example is the work of Malmbrandt and Ahlstrom (2013). The authors developed and empirically validated an istrument for assessing the adoption of lean in services. The assement instrument containes 34 quantitative measures and qualitative practices, organized into three groups: *enablers*, i.e. aspects necessary for achieving behavioral and cultural change for the adoption of lean such as management and employee commitment, training and resource allocation in CI; *lean practices*, i.e. practices able to support lean principles such as customer value, waste identification, flow, etc. (the authors used the most cited lean principles); and *performance*, i.e. six key performance measures including *lead time*, *inventory*, *productivity*, *quality*, *cost*, and *customer satisfaction*.

In reviewing past results, there is an obvious gap in assessing the degree of *leanness and sustainability* in service industries. The existing assessment approaches were exclusively based on relevant work done in manufacturing. Although some authors suggest that more adaptations from manufacturing are expected to occur (Narayanamurthy and Gurumurthy, 2016), in our view lean assessment tools need to capture more service and/or industry specific characteristics (such as those in healthcare, education, financial services, etc.). Given the lack of a widely accepted *leanness* index in services, there are less opportunities to compare and benchmark performance across organisatons, and thus it is more challenging to assess the contribution of existing lean practices to the overall performance of an organization.

2.5.3 Barriers and critical success factors of continuous improvement

In Section 2.5.1 we discussed the *dynamic capabilities* that an organization needs to develop in order to continuously improve. In this Section we examine the *barriers and critical success factors* related to these capabilities. We organize the barriers and critical success factors for CI in two groups: the first concerns the *dynamics of the improvement process* and the second the *dynamics of responding to changes in the environment.* These are different from the ones presented in Section 2.4.3, since the capabilities to achieve high performance are different from those required to sustain it (Su, 2016).

In terms of the *dynamics of the improvement process*, a highly cited barrier and success factor for CI is the way *objectives (*i.e. *performance targets*) and *resources* are set and managed at the beginning, during and following a lean transformation. As already discussed, the *improvement paradox* suggests that while job security benefits an organization in the long-run (as higher commitment leads to higher quality), maintaining resources (as opposed to letting them go as a result of early successes of the program) worsens financial performance (Keating *et al.*, 1999). Senior managers, therefore, need to balance *short versus long-term objectives* taking into account performance improvement patterns and market conditions (Sterman *et al.*, 1997).

Improvement initiatives typically follow a *"worse-before-better"* (Keating *et al.*, 1999) or an S-curve pattern (Netland and Ferdows, 2016), suggesting that improvement is typically slow at the beginning, then grow rapidly and finally taper off. In addition, the "*improvement half-life*" pattern (Schneiderman, 1999) suggests that the time required to cut defects in half increases as the technical and organizational complexity of a process increases[10]. These patterns have important implications: first managers need to be aware and prepared for a period during which performance and cost may erode. However this is not always the case. As Keating *et al.* (1999) state: "*many prior improvement programs had failed because management could not understand or tolerate the initial drop in availability and rise in costs*". Second, performance targets should be set in accordance to the stage of the transformation as well as on the

[10] Indicatively the product development half-life ranges from 36-48 months, manufacturing from 12-24 months and, individual machine 6 months.

complexity of the transformed processes; for example, setting stretched instead of moderate targets at the beginning of a transformation process might discourage managers, employees and senior management, who are not conscious about this pattern and eventually might terminate the transformation (Netland and Ferdows, 2016). Third, focusing only on short-term gains (by cutting costs or raising throughput targets), increases the pressure to work harder and eventually reduces the time dedicated for improvement, which in turn undermines long-term commitment and sustainable improvement (Sterman *et al.*, 1997).

Furthermore, senior managers need to consider how their organization can absorb productivity gains while minimizing the negative consequences of market conditions. For instance, launching improvement programs at times of economic recession or in mature industries, might increase the pressure for layoffs, which in turn might reduce employee commitment to improvement. In addition, in cases in which successful improvements create too much additional demand (e.g. product quality improves dramatically), the organization needs to be prepared to absorb this new demand and maintain the quality levels that led to their success (Keating *et al.*, 1999).

Past research suggests a number of actions to address the above challenges (Sterman *et al.*, 1997; Keating *et al.*, 1999): involving employees to the design and implementation of improvement initiatives by dedicating a portion of employees' time to improvement efforts, mandating their participation in training, and relating financial incentives and performance evaluation to continuous improvement. Management may also communicate the importance of improvement as well as the point that it is in the employee's best interests to participate to improvement initiatives despite the threat of job losses, in the sense that the loss of some jobs is better than the loss of all jobs. Managers can also prioritize slow improving processes first, so that any increase in demand can be absorbed by the available capacity. Also lowering desired throughput (through marketing and sales) can reduce the pressure to the employees. Finally, resources freed up due to productivity gains should be reinvested into the search for new and greater improvement opportunities, building on the positive momentum of initial successes.

In terms of barriers in *responding dynamically to changes of the environment*, past research (mostly derived from the quality literature), suggests the development of three capabilities (Su *et al.*, 2014; Su, 2016):

The first is *meta-learning*, i.e. the ability of an organization to better learn and systematically improve the first-order (e.g. detecting and correcting quality defects) and second-order (e.g. understanding the underlying causes of problems) learning processes. This capability eventually leads to innovation and continuous improvement and is supported by a disciplined practice of continuously renewing the quality system so that it improves in relation to the competition. In particular, this capability is essential for the healthcare industry, where the adequacy of existing methods and approaches in evaluating improvements is not sufficient (Berwick, 2008). Similarly, there is a need for more sophisticated and advanced improvement tools for complex processes like product development (Keating *et al.*, 1999).

The second is *sensing weak signals*, i.e. the ability to monitor (operations, customers and the environment), detect and prevent sudden changes that could disrupt (quality) performance in the organization. This capability is supported by practices that promote employee attentiveness to emerging changes (internally and externally) and the visibility of small anomalies by collecting and analyzing data.

The third capability is *resilience to quality disruptions*, i.e. the ability of organizations to quickly adapt and recover from (quality) disruptions. This capability is supported by policies enabling self-organizing teams through training programs, selective hiring, knowledge sharing, real-time communication, collaboration and reward system that supports teamwork and CI (Poksinska and Swartling, 2018).

Given the limited research in the service literature on the topic of CI, we developed the current Section with insights derived mostly from manufacturing research. Although the insights seem relevant for services as well, more research is needed to validate the above findings in specific service settings.

2.6 Gaps and focus of this dissertation

In the previous Sections of the current Chapter we have decoded LM by examining its historical evolution and key components, its impact and limitations, and finally the aspects that have made this approach revolutionary. Moreover, we critically reviewed three distinct streams of the literature that concerns lean in services. In particular, we reviewed a) *applicability* of lean in services, i.e. the relevance and limitations of the lean concepts to services, b) *transferability*, i.e. implementation cases of lean in services, and c) *sustainability*, i.e. the conditions to maintain continuous improvement in service organizations.

The above analysis has helped us identify important gaps in the existing literature in regard to the extent that some important LM concepts can be adopted and adapted in service environments. We summarize the gaps in Section 2.6.1 and highlight the ones to be addressed in the current dissertation in Section 2.6.2.

2.6.1 Gaps in lean service literature

Our review indicates that the literature on LS, since the introduction of the concept in 1998 by Bowen and Youngdahl (1998), attracted significant attention in the period 2010-13; interest has plateaued since then (Gupta *et al.*, 2016). Early research revealed that service industries have been using some lean concepts, although not labelled as such; for example, all service firms have some degree of standardization in their operations, apply some form of visual management or use practices with similar objectives with those of LM. Indicatively, reservation systems and yield management have been used for years in the hospitality and airline industries to smooth demand and achieve uniform loads, similar to production smoothing in manufacturing (Duclos *et al.*, 1995; Nathan and Trinkaus, 1996; Yasin, Small, and Wafa, 2003).

Much of LS research has been either too conceptual, i.e. lacking empirical validation, or too narrow, i.e. studies focusing exclusively on the application of selected lean practices (e.g. value stream mapping) in certain functions and sectors (e.g. emergency department in healthcare). Although case studies have reported significant benefits, these oftentimes are based on anecdotal evidence with no systematic investigation on the factors and mechanisms that affect and promote generalization (e.g. no studies report failed lean service implementations systematically) (D'Andreamatteo *et al.*, 2015; Costa and Filho, 2016).

From the contextual standpoint, most authors and practitioners agree that lean is applicable and may have significant impact to *manufacturing-like* services i.e. services with repetitive operations, high volumes, and/or tangible characteristics, such as inventory. For example, given that most hospitals spend about 35% of their budget on inventories, as well as supplies and the associated personnel involved in managing this inventory, one may assume that there is significant benefit from applying lean concepts in these settings (Nathan and Trinkaus, 1996; Yasin, Small, and Wafa, 2003).

As services become more knowledge and customer-interaction intensive, lean principles are still applicable; however, the implementation of these principles to practices needs to be adjusted to the individual characteristics and purpose of each service. Overall, *"lean methodology cannot be implemented in the same way in every situation: it needs to be tailored* *to the particular characteristics of each service sector"* (Bowen and Youngdahl, 1998; Ahlstrom, 2004; Womack, 2005; Liker and Morgan, 2006; Piercy and Rich, 2009).

Nevertheless, there are limited insights as to *what* should be adjusted and *why* any adjustment is needed based on the characteristics of the environment (Seddon *et al.*, 2011). Some authors (Ahlstrom, 2004; Radnor and Walley, 2008) draw attention to the following implementation aspects: a) the need to adopt a holistic process-based view, b) the importance of linking lean initiatives to long-term objectives and strategy, and c) the limitation of applying cross-training in knowledge intensive jobs and the concept of pull in information intensive services.

In the next paragraphs we summarize ten areas (gaps) that, to the author's view, merit further investigation in order to reveal the factors that affect the implementation of lean in services.

1. *Need for more systematic research in information- and knowledge-intensive services*. Further clarity is needed on the definition and essence of lean in services. The LS concepts and solutions has been largely based on the work done in manufacturing. As a result, the same ambiguity found in the manufacturing literature (i.e. the essence of lean, its practices and their relevance in manufacturing environments other than repetitive manufacturing such as continuous flow, make-to-order, etc.) is encountered in services as well (Holm and Ahlstrom, 2010; Suárez-Barraza et al, 2012; Dos Leite and Vieira, 2015). Furthermore, our analysis has indicated that rigorous research is required to systematically document the impact of lean in services. Finally, there is a need to expand the related research in less investigated service sectors such as professional services (Prashar and Antony, 2018) or services that cut across different sectors (see professional supply chains by Harvey, 2016).
2. *Organizing the vast diversity and number of service areas*. Our research highlighted a rather known limitation of the existing service literature; that is, the lack of a commonly accepted classification approach for services. It seems that there are several ways of classifying services (see for example Silvestro *et al.*, 1992; Schmenner, 2004), but none of them is widely accepted. From a LS perspective, this limits the potential of organizing services in a robust way based on common characteristics in order to tailor the LS approach. These characteristics might affect the way lean is defined, assessed and applied and eventually might determine the generalization of lean in services (Malmbrandt and Ahlstrom, 2013).

Using the framework (introduced in Section 2.2.3) of the aspects that made LM revolutionary in the automotive industry (Hopp and Spearman, 2001; Holweg, 2007) we discuss some additional gaps in the LS literature.

3. *The role of technological advancements in developing lean services*. The technological advancements in Toyota, such as the flexible equipment and the *"autonomation"* of machines (i.e. *"intelligent"* machines able to detect defects and stop production automatically), although contributed to the development of some of TPS most famous practices (e.g. setup reduction, quality and flexibility), they have not been investigated thoroughly in the LM literature. Given that most services have a large technological component, we expect technology to continue playing a central theme in the transformation of service sectors. To the author's best knowledge, none of the existing research efforts or case studies have explored the role of technology in developing lean services. This constitutes an important gap in the existing lean service literature, which is becoming more relevant under the light of the so-called fourth industrial revolution or "*Industry 4.0"*, in which new technologies (such as voice recognition, voice and text mining, robotics, etc.) and recent developments in Artificial Intelligence (AI) are transforming the service sector and are expected to replace human labor at great scale. Therefore, the role of new technologies and AI in the context of lean services is an important future research topic (see recent examples from Lim *et al.*, 2018; Wirtz *et al.*, 2018; Keating, McColl-Kennedy, and Solnet, 2018; Subramony *et al.*, 2018).
4. *Exploring and expanding the holistic approach of lean in services*. The *holistic, systems* approach suggested by lean has been partially addressed in the past LS literature. Researchers have highlighted a few gaps in terms of *"holisticness"*, such as the need to extend the scope of lean implementations to the broader enterprise and link lean with strategy (Ahlstrom, 2004; Radnor and Walley, 2008). However, it seems that the important, tough challenges of service organizations (such as managing the customer, employee introduced variability, attrition, rationalizing and simplifying products related to services, overcoming integration challenges from IT legacy systems, inter-company collaborations, etc.) have not been addressed in the context of lean in services (or the solutions used to address some of those challenges were coming from manufacturing and were not intendent to solve problems in service organizations). To the author's experience, the holistic mindset has been hardly embedded in service organizations, in which the functional organization and silo mentality still prevails. A

typical example concerns *cellular work structures*, in which activities are integrated in the same work structure based on process similarity. There are limited references of the conditions that favor the use of cellular structures in services, a gap that we aim to investigate in the current dissertation.

5. *Using lean as a driver of innovation to reshape the service environment*. Toyota managers solved the business problem of producing high variety, high quality automobiles in limited quantities in the most efficient way. To do so, they challenged some of the most fundamental constrains under which the automotive industry used to operate. They questioned, for example, the long setup times that called for large batches, and worked proactively to reduce them by introducing innovative practices. This and other practices transformed the entire industry, as they are now considered *standards* and used (more or less) by all major players. However, to the author's best knowledge, there are very few references indicating *step-change improvements* resulting from lean initiatives in services, despite the profound benefits reported by the relevant case studies. One of these references is comparing call center traffic to setup in manufacturing, in the sense that call volumes are not exogenously determined, but can be reduced by intervening in the design and management of services (Seddon, 2005, 2007; Seddon *et al.*, 2011; Hatzakis *et al.*, 2010). However, there are no explicit rules that could be used in every call center nor it is clear how to deal with other constraints that might exist in other service environments (not using call centers). Another innovation that appears to be having a major impact in surgery procedures is the introduction of a 19-item pre-surgery checklist to improve team communication and reduce complications and deaths associated with surgery (Haynes *et al.*, 2009). The *innovative* aspect of lean is a gap in the existing service literature that deserves further investigation.
6. *Focus on service related operational details and specific challenges*. The importance of understanding and appreciating operational details at all managerial levels has been emphasized in the past LM literature as a way to understand system performance and pursue further opportunities for waste reduction. However, lean practitioners and authors have used the types of waste that are common in manufacturing and not necessarily the ones specific to service sectors (e.g. physical inventory is not relevant for information-intensive services, such as financial and professional services). Furthermore, the types of waste used lack detailed definitions or they are not linked to professional services (e.g. how can one define over-processing waste in performing a

cardiothoracic surgery?). Finally, the variability introduced by the customers, as well as the effort and experience of the customer when s/he uses a certain service, has not been considered in most lean implementation studies. A possible reason is that in manufacturing, production managers did not have to cope with such a challenge. Therefore, a significant contribution to the existing LS literature would be to introduce more relevant types of waste in services and especially the ones related to the *customer experience* pre-during- and-post service consumption (Lemon and Verhoef, 2016; Rajnish, Jayesh, and Shilpa, 2017).

7. *Importance of controlling WIP in services*. The importance of controlling WIP levels (i.e. pull) as a means to shorten cycle time and keep quality at appropriate levels had been realized by Toyota and its managers early on. However, as we discussed previously in this dissertation, this has not been clear in the broader lean community for some time. This lack of clarity (i.e. of what pull really is), has led some service researchers to ascertain that pull is not applicable to services because services are inseparable (i.e. production and consumption occurs simultaneously). In addition, the fact that in information-intensive services physical inventory does not exist, has led to another (false) belief that service requests or customers waiting in queues are some short of inventory, while in reality this aspect may be considered as a time buffer. The concept of pull is, therefore, an important topic that requires further investigation in the context of LS.
8. *Importance of pursuing flexibility*. Resource flexibility is one of the LS components that has been applied successfully in past implementation studies (see Piercy and Rich, 2009a, 2009b). However, there are two areas regarding resource-flexibility in services that need further investigation. The first relates to the practices used to train, motivate, measure performance and compensate white-collar workers, as opposed to blue-collar ones. The former have more sophisticated needs in terms of performance and knowledge management (Hopp *et al.*, 2009; Asif, *et al.*, 2010). Therefore, there is an immediate need to incorporate in the LS body of knowledge the latest best practices in developing and cross training knowledge-intensive professionals. The second refers to standardization in services. This is a critical design consideration which has not been applied as successfully in (all types of) services as in manufacturing. Therefore, more explicit research is needed in which areas, at what degree and how to apply standardization in different types of services.

9. *Priority on service quality versus throughput*. By reviewing the various implementation cases, it seems that quality and rework is most probably the most significant source of waste found in services, especially in healthcare and financial services. However, for some types of services (mostly knowledge intensive ones) their intangible nature and inherent variability make it challenging to define and measure service quality. Furthermore, and as already discussed, quality may be used as a buffer for service workers to cope with increased demand. The selection of policies that make optimal use of variability buffers (including quality as a fourth buffer) has not been investigated in lean service operations. In the current dissertation we aim to shed more light on the impact of quality on service operations.
10. *Necessity of continuous improvement (CI)*. Finally, as discussed earlier, CI and the *dynamic capabilities* that service organizations need to develop in order to continuously improve is a critical issue. There is a distinct need to validate the existing findings with studies in various service sectors, since the insights around CI are derived mostly from manufacturing research (see Section 2.5). Deeper investigation is required in two areas: the first, refers to the *human resource practices* that would enable and motivate white-collar employees to drive CI. The second refers to best practices in implementing and transitioning to a lean enterprise (e.g. planned vs. emergent change as suggested by Seddon *et al.*, 2011). Our analysis has revealed various implementation approaches; however, more work is needed for identifying an appropriate approach to transform a service organization taking into account factors such as disruption of operations, dispersed networks, time and cost.

2.6.2 Gaps addressed in this dissertation

The contribution of the current dissertation[11] involves insights in the following gaps identified above:

1st Gap: we discussed the need to explore the application of lean in more complex service environments. The current dissertation partially addresses this need, as we investigate two case studies in a low volume-high complexity service setting in financial services (equivalent to the

[11] The contribution of the dissertation has been already overviewed in Section 1.4. In this Section we summarize our contribution in relation to the gaps identified in the literature.

traditional job shop in manufacturing). This environment is similar to many other settings in services; hence the insights gained from the work in this dissertation have broader applicability.

We also discussed the need to remove some of the ambiguity around lean. In the current Chapter we provided a definition for lean in services, proposed the main principles and frameworks and finally, the limitations and extensions (i.e. challenges not found in manufacturing) of applying lean in a service setting, mapped in six distinct managerial areas (i.e. service package and process design, buffer management, scheduling and queueing, quality management, performance management, people and organization management). These outcomes contribute towards closing the related gap and can be used as a reference to guide future research.

2nd Gap: we discussed the need to introduce a classification system that may affect the generalization and transferability of lean in services. We address this gap (in Chapter 3) by first exploring past classification frameworks in relation to some fundamental questions. For example, what are the key attributes (used in the most cited service classifications) that differentiate manufacturing from services and differentiate among services? For which processes in the service lifecycle are these attributes most relevant? How can these attributes affect the applicability of lean in services? Subsequently, we proposed a new classification scheme that addresses these questions. The related analysis may be especially useful in service areas in which traditional lean concepts stemming from manufacturing need to be modified.

4th Gap: cellular manufacturing, a very well-known concept in the LM literature has been less explored in services. In the current dissertation (Chapter 5) we investigate the appropriateness of cellular work structures for information intensive services. Most importantly, we explore the effects that some unique service characteristics may have in the applicability of cellular structures in services. This encompasses aspects that range from employee behavior (e.g. how employees react to changes in a system's workload and overwork) to the setup reduction that can be achieved by grouping similar tasks in the service setting (e.g. how large the setup reduction should be to justify the conversion from a functional to a cellular structure).

9th Gap: finally, given the importance of quality in services (probably the biggest source of waste in services), we investigate (Chapter 4) the impact of quality failures in service efficiency. For example, we attempt to answer important questions such as: what is the impact of quality failures in various aspects of performance? How effective are some of the most common managerial practices to respond to quality failures? Which factors are critical for the efficient management of failures? We expect the answers to these questions to provide more insights to service managers regarding the most effective strategies for addressing the impact of quality failures in services.

Chapter 3. Classification of services[12]

3.1 Introduction

As already mentioned in the introduction, researchers from various fields (economics, marketing, operations etc.), have attempted to define and analyze the nature of services, in a period during which the role of the service sector has been increasing both in terms of contribution to the gross domestic product and in terms of importance to employment. As a result of these efforts, several approaches have emerged defining services as opposed to goods and identifying their generic characteristics. The common element in most service definitions (Hill, 1977; Sasser, 1976; Sasser 1978, Lovelock, 1983, Gronroos 1988, Vargo and Lusch,

[12] Most of the work in this chapter has been published in the paper "Service attribute-process matrix: A tool for designing and managing services" (Gliatis and Minis, 2007)

2004) is that services are considered to be *activities* or *processes* in which "*the dominant object of transformation is the customer with several objects of information and less materials, while in manufacturing the predominant input for processing is the material*" (Moris and Johnston, 1987).

Based on this distinction between goods and services, the bibliography proposes a series of features that characterize services (service characteristics). During service delivery, the *customer participates* in the process and can intervene often to demand additional service of a particular kind or to request that some aspects of the service be changed. Also, the customer usually *depends on the server* in order for the delivery of the service to be complete. This close customer - server interaction reveals another important characteristic during service delivery: *Inseparability* of production and consumption; that is, the producer - consumer interaction is necessary for the service to be delivered.

In addition to characteristics related to the input and the processing of services, the output of most services is *intangible* in nature. Furthermore, if the output of services is not consumed at the time of delivery, it is forever lost and *perishes*, and thus there can be no accumulation of inventory. As a result, this output may *vary* significantly (*heterogeneity*), creating uncertainty regarding process time, service quality and cost. Finally, while the *ownership* of any good could be transferred from one economic unit to the other, such exchange is not possible in services.

Two sources of debate have been raised regarding the above characteristics: a) some of these are also applicable to manufacturing, and b) they are not universal and change with technological progress, especially with the use of internet and other self-service technologies (SST). Concerning this criticism one of the top service scholars in the survey contacted by Edvardsson, Gustafsson, and Roos (2005) states: "*These generic characteristics are helpful in understanding the nature of services if they are properly qualified. They are not as universal as originally posited and, because they are not, we don't need to discard them, but we need to understand the conditions under which they do and do not apply*".

To encompass the full diversity of services and their complexity, authors have proposed various classification schemes (Cook, Goh, and Chung, 1999; Dotchin and Oakland, 1994) which are presented in the following Section.

3.2 Review of the relevant literature

The first attempts to classify services were focused on the distinction between marketing of services and marketing of goods (Bucklin, 1963; Judd, 1964; Rathmell, 1966; Hill, 1977; Shostack, 1977; Lovelock, 1983; Shostack, 1987; Stell and Donoho, 1996). Chase (1978) was the first to focus on operational issues, characterizing services based on the extent of customer contact, and providing strong managerial insights on how to design and manage service operations. The work of Hayes and Wheelwright (1979), on the product-process matrix for manufacturing, has inspired a number of attempts to classify services in a similar way (Thomas, 1978; Mills and Margulies, 1980; Maister and Lovelock, 1982; Schmenner, 1986; Wemmerlöv, 1989; Haynes, 1990; Silvestro, Fitzgerald, and Johnston, 1992; Kellogg and Nie, 1995; Tinnila and Vepsalainen, 1995; Collier and Meyer, 1998, Buzacott, 2000).

Most of the above authors classify services based on two attributes resulting to the creation of a two–by–two matrix (each axis of which corresponds to one of the two attributes). Significant types of services are positioned either in each quadrant of the matrix (e.g. Maister and Lovelock, 1982) or on its diagonal (e.g. Kellogg and Nie, 1995; Buzacott, 2000). Different managerial implications are related to each quadrant (or each position in the diagonal), supporting service managers in selecting the appropriate strategies.

Although the proposed classification models provide considerable insights for managing and designing services, many of them have been subject to criticism (Snyder, Cox, and Jesse, 1982; Haynes, 1990; Silvestro *et al.*, 1992; Tinnila and Vepsalainen, 1995; Kellogg and Nie, 1995; Collier and Meyer, 1998; Cook *et al.*, 1999; Buzacott, 2000), which can be summarized as follows: The resulting models are difficult to interpret, using ambiguous and generic criteria and parameters; they have a limited focus, addressing selected service issues and do not provide an integrated view of services; they fail to define the relationship between the service and the service delivery process; they lack cohesive framework and have not been tested empirically.

Despite this criticism, service classification has been proven useful in several ways (Chase, 1981; Schmenner, 1986; Kellogg and Nie, 1995; Tinnila and Vepsalainen, 1995). The proposed schemes allowed service firms to gain strategic insights based on their position as defined by the characteristics of the services been offered, and by taking into consideration possible development options. Furthermore, service classification models provided structure and new tools to enhance understanding of productivity, the nature of customer interaction and its relationship to service delivery mechanisms. Finally, service classification has provided insights and rationale on how some leading service organizations have been able to sustain their competitive positions for decades.

In this Chapter we exploit selected results of past work in order to a) define the principal attributes to be considered in service process management, and b) identify relationships between them. We provide a method to identify the importance of these attributes in each process of the service life cycle in order to better design and manage service offerings.

3.3 The Service Attribute-Process Matrix

The Service Attribute-Process Matrix (SAPM) links the service classification attributes with the processes of the service life cycle. This is done since a service is produced through a sequence of processes, ranging from strategy development to the management of financial and other resources. Each of these processes generates a different value for the service; this value, in turn, depends both on the unique service characteristics (service attributes) and the way the process accounts for these characteristics. Thus, a service characteristic has a different influence on each process of the life cycle. This fact prompted us to relate service attributes with the service processes using a standard framework.

The layout of SAPM resembles that of House of Quality (Hauser and Clausing, 1998) and comprises seven parts (Figure 3.1), which are described below; however, the two methods are quite different as will be evident in the following discussion.

The vertical axis (part I in Figure 3.1) represents the service classification attributes as synthesized from selected results of the service literature. The service classification attributes are presented in Table B.1 of Appendix B:. These attributes have been grouped in six distinct service dimensions (part II) based on considerations for the customer, the service provider and their interaction.

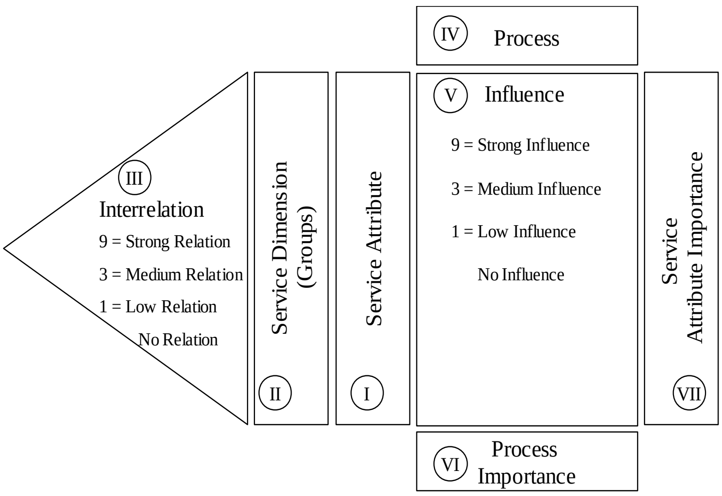


Figure 3.1: Layout of SAPM

With respect to the customer we have identified the following dimensions:

1.0 *Customer's Buying Motives*, i.e. attributes related to the motives that direct customer's behavior and

2.0 *Customer's Buying Practices*, i.e. attributes related to the way a customer practices its buying preferences.

With respect to the customer-provider interface we have identified the following dimension:

3.0 *Ways of Service Delivery*, i.e. attributes related to the methods used by service organizations to deliver service offerings.

Finally, with respect to the service provider, we have identified the following dimensions:

4.0 *Ways of Service Production*, i.e. operation related attributes;

5.0 *Service Output Characteristics*, i.e attributes related to the nature of the end result of services; and

6.0 *Service Management Considerations*, i.e. important attributes for management to consider while making decisions concerning service execution.

Since these attributes have been selected from the literature and were not constructed on a zero basis, they are not independent; the relationships between them are analyzed, based on relevant literature references and the authors experience in service industries, in part III of SAPM.

The horizontal axis (IV) represents the major processes in the service life cycle. For this purpose, we have adopted the Process Classification Framework, originally proposed by the American Productivity and Quality Center (APQC, 1992). In this framework, the high level processes of an organization have been grouped into two broad categories: Operating processes, and Management and Support processes.

These include the Operating processes:

1.0 *Develop Vision and Strategy*,

2.0 *Design and Develop Products and Services*,

3.0 *Market and Sell Products and Services*,

4.0 *Deliver Products and Services*,

5.0 Manage Customer Service.

and selected Management and Support processes considered critical for the service life cycle:

6.0 *Develop and Manage Human Capital*,

7.0 *Manage Information Technology and Knowledge*,

8.0 *Manage Financial Resources*.

The influence of each service attribute in the design and/or management of processes within the service life cycle has been evaluated (in an appropriate scale) in part V of SAMP. The evaluation was based on the managerial implications found in the service classification literature (Chase, 1978, 1981; Snyder *et al.* 1982; Lovelock, 1983; Wemmerlöv, 1989; Kellogg and Nie, 1995; Tinnila and Vepsalainen, 1995; Collier and Meyer, 1998) as well as on the author's experience in banking, transportation and the professional services industry (in cases where literature references were missing). Finally, the total score of each column reveals the relative influence of all service attributes on the corresponding process (part VI), while the total score of each row reveals the relative importance of each service attribute along the entire life cycle of a service (part VII).

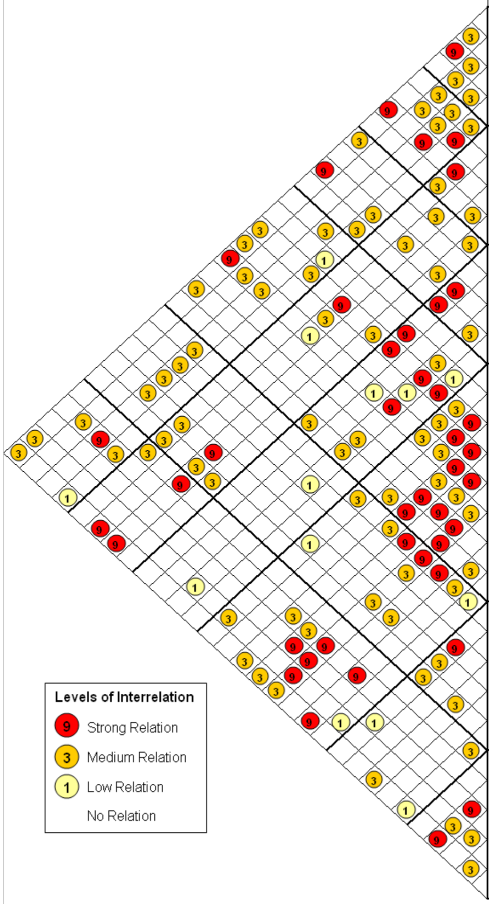
Lately, great emphasis and interest has been placed on e-services, as the combination of self-service and technology transform the ability of service organizations to deliver services with little or no human interaction, achieving low cost and large volumes (Rowley, 2006; Salomann, Kolbe, and Brenner, 2006; Chase and Apte, 2007; Hofacker, Goldsmith, Bridges, and Swilley, 2007). SAPM attributes are relevant to e-services, since the core aspects of these services (i.e. the self-service concept and the substitution of human activity by machines) have been identified by traditional service scholars and service practitioners (Lovelock and Young, 1979). For example, attributes in SAPM such as: *Necessity of customer's presence* (2.2), *Service Delivery Channel* (3.3), *Priorities Serving rules* (3.4) (including Self-Service) and *Direct Provider of the Service* (4.2) (equipment vs people) may well be applied to e-services with suitable adaptations. Finally, since the e-service literature is still evolving we expect some new classification attributes specific to e-services to emerge, e.g. see the work of Sung-Eui and Park, (2002) and Sung-Eui (2005), which, after appropriate validation, should be included into SAPM.

3.4 Influential attributes and complex processes

The completed SAPM is presented in Figure 3.2. As mentioned in the previous Section the value of each cell Cij of part VI of SAPM ranks the importance of service attribute i for process j in a scale 1-3-9 (see Figure 3.2). This scale is simple and common quantitative method in design research. However, one may use more sophisticated and robust evaluation schemes based on expert judgment. For example, the Delphi method may be suitable here (Linstone and Turoff, 2002).

By summing the scores corresponding to each row, one can determine the most influential service attributes across the entire service life cycle. By simple inspection of the last column of SAPM it appears that the top five most influential attributes are: *Extent of Customer Contact* (4.3), *Customization/ Routinization* (4.5), *Service Delivery Channel* (3.3), *Customer's Influence* (4.4), *Type of customer* (1.1). The influence of these attributes in selected processes is discussed in Section 3.5 bellow.

By summing the scores correspondingly to each column of SAPM, one can determine the complexity of each process in the service life cycle; that is, a process which is influenced strongly by many service attributes, is considered to be complex, since managers need to consider all these attributes in the design, planning and execution of the related activities. According to this criterion the top three most complex processes are: *2.0 Design and Develop Products and Services*, *3.0 Market and Sell Products and Services* and *4.0 Deliver Products and Services*.



Dimensions	Processes / Services Attributes	1.0 Develop Vision and Strategy	2.0 Design and Develop Products and Services	3.0 Market and Sell Products and Services	4.0 Deliver Products and Services	5.0 Manage Customer Service	6.0 Develop and Manage Human Capital	7.0 Manage Information Technology and Knowledge	8.0 Manage Financial Resources	Total Score
1.0 Customer's Buying Motives	1. Type of customer	9	3	9	9	3	9	3		45
	2. Perceived risk		9	9		3	1			22
	3. Service Importance	3	9	9	3	3	1	9		37
	4. Purchase effort		9	9	3		1			22
2.0 Customer's Buying Practices	1. Customer's Commitment		3	9	3	9	3			27
	2. Necessity of customer's presence		9	3	9	9	9			39
	3. Demand Fluctuations (patterns)		3	3	9	3	1			19
	4. Type of Relationship		9	3	3	3	9	3	1	31
3.0 Ways of Service Delivery	1. Interaction between Customer and Service Organization		3	3	9	9	9			33
	2. Nature of Service Delivery		3	9	3	9	9			33
	3. Service Delivery Channel	9	9	9	9	3	3	3	3	48
	4. Priorities Serving rules	3	9	3	9	9				33
4.0 Ways of Service Production	1. Object processed		3	9	9	3	3	3		30
	2. Direct Provider of the Service		3	9	9	3	9	3		36
	3. Extent of Customer contact	9	9	9	9	9	9			54
	4. Customer's Influence	9	9	3	9	9	9			48
	5. Customization/ routinization	9	9	9	9	3	9	3		51
	6. Product/ process focus		3	9	9	3	9			33
	7. Personnel Judgment		9	3	9	9	9	3		42
	8. Value added, back office/ front office		3		9	9	9			30
5.0 Service Output Characteristics	1. Degree of Tangibility		9	9	9	1	3	3		34
	2. Individual/collective services		3	9		1		3		16
	3. Ownership		3	9	1					13
	4. Single Service/ Bundle of Services		9	9	9					27
	5. Timing and Duration of benefits		9	9	3	3				24
6.0 Service Management Considerations	1. Extent to Which Supply is Constrained	3	3	9	9	9	9			42
	2. Management's degree of control	3	9	3	9	9	3			36
	3. Perceived risk for the company	3	9	9	3	9	3	3	3	42
	4. Production (& Transaction) Cost		9	3	9			9	3	33
	5. Degree of regulation	3	9	1	3	9	1		1	27
	Total Score	54	195	190	187	149	131	45	11	

Figure 3.2: Service Attribute-Process Matrix

Based on the above discussion it appears that SAPM may be used as a tool in service system engineering, to support the system designer in two important ways: i) By identifying those service attributes with the most significant impact on the entire system life cycle, it helps designers to focus on these attributes and engineer the service delivery system in a way that balances the effects of each attribute across the entire spectrum of life cycle processes, thus promoting an integrated system development. ii) Conversely, for each individual process of the life cycle, SAPM determines the service attributes that affect it the most, as well as the interrelationships among these attributes (part III of SAPM). Thus, it allows designers to manage process complexity by trading-off among these service attributes. It is also noted that SAPM can be used for further analysis down to a sub-process or an activity level.

3.5 Using SAPM for decision making

As an application of SAPM, we explore those service attributes that may exert strong influence (ranked as 9) in selected processes of the business cycle. We chose two such processes (marked in gray background in Figure 3.2); that is the development of the firm's vision and strategy and the service delivery process. These processes are equally important but differ in complexity. This is also apparent by the numbers of attributes that exert strong influence in each process.

3.5.1 Develop vision and strategy

The design of a service firm's strategy involves four major elements (Heskett, 1987), each of which is explored bellow using SAPM.

a. *Who is the customer?* The first element refers to the identification of the target market. The related attribute of SAPM that influences vision and strategy is the *Type of Customer* (1.1 in part I of SAPM) as well as related attributes in the *Customer's Buying Motives* and *Customer's Buying Practices* dimensions.
b. *How do we differentiate our service in the market?* This second element refers to the service concept, which is strongly affected by SAPM attributes *Customer's Influence* (4.4) and *Customization/ Routinization* (4.5). As mentioned by Kellogg and Nie (1995), "*Service firms with high customization and great customer participation in the creation of the service are more likely to pursue a differentiation strategy. On the contrary, firms offering services with low customization and low customer participation are more likely to use a cost leadership strategy*". They also argue, "*Differentiation does not ignore costs, but rather emphasizes the quality and uniqueness of the service at a cost that targeted customers are willing to pay. The emphasis is on the value of the service, rather than on its costs. On the other hand, the essence of cost leadership is to provide low cost of service, low prices, standardized services and high volumes*".
c. *What is our service package and the operating focus of our service?* The third element shaping a firm's strategy is the service-operating concept, which is influenced by *Customer Contact* (4.3). Chase (1978) argues that "*Management should question whether a service strength lies in high contact or low contact, and it should encourage reflection on what constitutes an optimal balance between the two types of operations relative to resource allocation and market emphasis*". Once the firm's management has selected the mix of high and low contact services, it could explore a) the operating focus for competing effectively with respect to each type of services, e.g. for high contact services: Variety and treatment, while for low contact services: Price and speed; b)

opportunities to change the contact time for specific services, e.g. increase or decrease contact time in service delivery (Chase, 1981).

d. *What are the actual processes, facilities and staff, by which the service is created?* The fourth element refers to the service delivery system, aspects of which will be further discussed in the following Section. At the strategic level, however, the types and size of the *Service Delivery Channels* (3.3) should be considered for implementing the firm's strategy. As it is suggested by Tinnila and Vepsalainen (1995), companies should select appropriate alternative types of delivery channels based on the complexity and contingencies involved. For example, services of high complexity should be delivered through direct interaction with the customer, while standardized services could be delivered through self-service channels (e.g. ATMs, Internet).

Moreover, service firms should balance the services offered, (those provided as core services as well as those that complement them) with the available delivery channels. This should create a meaningful synergy between traditional and new channels supporting the overall strategy of the service provider (Berman and Thelen, 2004; Simons and Bouwman, 2005).

3.5.2 Deliver products and services

The service delivery process includes four areas, each of which is related to different level of operating decisions. *Facility Design* includes strategic level operating decisions, *Forecasting* as well as *Service Capacity* and *Resource Planning*, tactical level decisions and, finally, *Execution Management*, operational day-to-day decisions. Each of these areas is explored using SAPM and the corresponding significant attributes.

3.5.2.1 Facility design

The design of the service facility is one of the key elements for service operations. As discussed in the previous Section, the selection of the market that each facility will serve, and the type of services that each facility will provide, generates a series of additional decisions for the design of the entire service facility network:

a. *What role each facility should play?* Service facilities can be classified in two broad categories: Facilities that serve directly the customer (face-to-face contact or through alternative channels) and supporting facilities (or back office). While facilities, in many cases, are operationally autonomous, the decision to separate certain processes and centralize them in supporting units, depends on the following attributes indicated in SAPM: extent on which *Value is created in Back office or Front office operations* (4.8), on degree of *Customization/ Routinization* (4.5) of the service processes and the *Production Cost* (6.4). Hence, rigid service processes (Wemmerlöv, 1989; Safizadeh, Field, and Ritzman, 2003) that involve low level of task variety, low level of technical skills, few judgment decisions, high volume of information/ people/ goods handled per unit, can be performed by central supporting units in order to minimize production cost by leveraging economies of scale.

b. *Where each facility should be located and how much capacity should be allocated in each facility?* Decisions related to facility location are closely linked to market needs. These needs also affect the number of sites to be used and the size and characteristics of each site. Thus, *Necessity of Customer's Presence* (2.2), *Extent of Customer Contact* (4.3) and *Interaction between Customer and Service Organization* (3.1), play a significant role in facility location decisions. Under this perspective, the operations of high-contact systems must be close to the customer and additional location criteria should maximize the net profit potential of various sites. In low-contact systems, operations (or supporting facilities) must be near supply, transportation and labor in order to minimize costs (Chase, 1978).

c. *What is the preferred Facility Layout?* The design and arrangement of all premises should promote the facility role and therefore the firm’s value strategy and performance priorities (speed, price, variety, treatment, unique skills, etc.). For example, in *high-contact* (4.3) systems, where the customer’s presence is necessary, the facility should accommodate, among other things, the customer’s physical and psychological needs and expectations (Shostack, 1977; Bitner, 1992), while in low-contact systems, or back office operations, the facility layout should enhance production (Chase, 1978). As mentioned by Kellogg and Nie (1995), as we move from a system with high *Customer’s Influence* (4.4) and *high Customization* (4.5) to a system with routinized operations, the layout objectives move from flexibility to efficiency; e.g. minimization of customer distances, balancing of tasks among workstations. In low-contact systems, where back-office work dominates, the movement of information and materials is of real importance to operations. Thus, modern office layouts have more open spaces and visible displays, in order to enhance production and employee satisfaction by improving communication and empowering team working.

3.5.2.2 Forecasting

The forecast *accuracy* is highly depended on the ability to predict *Demand Fluctuations - Patterns* (2.3); that is the extent of fluctuations (variations) in demand over time. SAPM highlights attributes that affect demand fluctuations: *Type of Customer* (1.1), e.g. institutions are likely to have different habits than individuals; *Customer's Commitment* (2.1), e.g. the customer's propensity to easily switch between competing offerings might affect future demand; *Service Delivery Channels* (3.3), e.g. new sites and channels are likely to increase demand; and *Degree of compliance to regulations* (6.5), e.g. new government regulations may affect demand for specific services.

The *Single Service/ Bundle of Services* (5.4) attribute in SAPM, may significantly affect forecasting in the same way dependent demand affects forecasting in traditional manufacturing (Snyder *et al.,* 1982). Under this perspective, the level of detail under which the service is forecasted can be determined by classifying the dependent and independent components of each service package. Furthermore, in case that the service package consists of *Tangible* (5.1) elements and the *Object Processed* (4.1) includes materials, then demand for materials is considered dependent and should be predicted using the independent - dependent demand relationship.

3.5.2.3 Service capacity and resource planning

In services, unlike traditional manufacturing, demand must be met as it arises (with some exceptions), since, as previously mentioned, the intangible nature of a service does not permit inventories. Although service managers may employ several practices (off-peak pricing schemes, non-peak promotions, complementary services and reservation systems) to influence demand, (Sasser, 1976; Lovelock and Young, 1979), in the following paragraphs we explore some critical issues in service capacity planning using SAPM and its related attributes.

Service capacity becomes a dominant issue, since too much capacity generates excessive costs, while insufficient capacity leads to lost customers and poor service. The following SAPM attributes may influence service capacity: *Extent of Customer Contact* (4.3) plays a significant role, since in high-contact systems, capacity must be set to match pick demand, to avoid lost sales. In low-contact systems, storage of the output permits setting capacity at some average demand level (Chase, 1978). In addition the *Extent to Which Supply is Constrained* (6.1) refers to the extent to which peak demand can be met without a major delay (Lovelock, 1983). The challenge for the service organization is to manage capacity for meeting demand without affecting the quality of the service offerings; the best way to accomplish it, is to have flexible capacity capabilities to deliver a service when it is needed at the location needed. There are several practices used to achieve this, including: part-time employees, maximizing efficiency (prioritizing and performing only essential tasks, rearranging the service layout, multifunctional employees, etc.), increasing customer participation, sharing capacity, investing in the expansion ante (Sasser, 1976).

The critical issue for service managers is to select the appropriate practices for a given service. For example, a high level of *Customer Influence* (4.4), results in great variability and uncertainty into the service process, thus making capacity management more difficult; furthermore, service firms that offer *highly customized services* (4.5), face not only the uncertainty of customer arrivals but also the unique service requirements requested by each customer. Since service processes in such systems require specialized knowledge and skills, it is difficult to supplement service capacity with temporary labor, or automation. In contrast, since highly standardized services require minimal levels of training and simple tasks to complete, temporary hiring, cross training of employees, using the customer as a partial employee, technology and self-service can be effective (Kellogg and Nie, 1995).

3.5.2.4 Execution management

Management of service execution refers to the management of the day-to-day operations of a service organization. Typically, execution management includes: *Receiving clients and providing the required service*, *quality assurance*, and, finally, *the service recovery plan*.

a. *Receiving clients and providing the required service*. Matching the type of the service package with the appropriate delivery channel (Tinnila and Vepsalainen, 1995) sets the scene for receiving and serving customers as they enter into the service system, while keeping the selected operating focus. SAPM highlights several attributes to be considered during service execution. *Priorities serving rules* (3.4), are used to enhance both customer service and efficiency. There are several rules that can be applied, such as First come first serve, Reservations first, Shortest processing time, Emergencies first, Limited needs, Higher profit customer, Self Service etc. The challenge for the service organization is to select the appropriate rule, or combination of rules, based on the service characteristics. Attributes that may influence this decision include Service *Delivery Channel* (3.3), *Customization/ Routinization* (4.5), *Product/ Process focus* (4.6), and *Personnel Judgment* (4.7). For example in systems, where the focus is on the process and special skills to address task complexity, the customer is in the production schedule and must be accommodated. Thus, a first come first serve rule or a reservation system might be more suitable than a self-service system. On the other hand in systems, where the tasks are standardized, a self-service system might be more appropriate (Lovelock and Young, 1979). However, as "self-service technologies" (SST) (Bitner *et al.*, 2002) are increasingly used, it is becoming critical to address the loss of client control and the issue of customer retention resulting view of the lack of human interaction. Service organizations have to integrate their self-service activities with traditional customer interface points in order to balance high-tech and high-touch in customer relationships (Salomann *et al.*, 2006). Finally, in periods that demand increases unpredictably and, as a consequence, the service system operates under insufficient capacity, rules such as Shortest processing time, Emergencies first, Limited needs, can be applied to accommodate customers.

b. *Quality Assurance* refers to the measure that the service organization assumes in order to meet or exceed customer expectations. In services in which the nature of the output is intangible and the customer interacts with the service provider, main quality concerns include the technical and interpersonal skills of the employees as well as the consistency of service quality through all available delivery channels. *Customer's Influence* (4.4) and *Customization/ Routinization* (4.5) affect significantly quality assurance. For example, systems that provide custom services with extended customer influence, quality standards are often in the eye of the beholder and, hence, variable. Further insights on the influence of human issues in services are given in Cook *et al.* (2002). In routinized systems quality standards are generally measurable and, hence, fixed, and the requirements of the direct work force focus more on technical than interpersonal skills (Chase, 1978; Kellogg and Nie, 1995). More on service quality has been included in the SERVQUAL Model and the E-S-QUAL Model for e-services of Parasuraman *et al.* (1985, 2005). Additionally, the attribute *Service Delivery Channel* (3.3) becomes important in service quality, since in multi-channel servicing, channel functions have to be aligned within the overall service design, and they have to be managed in terms of quality and coherence throughout service delivery (Wootten, 2003).

c. *The service recovery plan* refers to the measures that a service organization establishes, in order to a) defuse negative reactions regarding the service package before the customer abandons the service system, and b) minimize the possibilities that something may go wrong in an exchange that could lead to loss exposure. Service organizations deal with these cases through appropriate identification of the fail possibilities in each service process. SAPM's attribute *Management's degree of control* designed into the service delivery system (6.2) refers to management decisions regarding the controls that the company has infused into the service delivery system and the available routes to deliver service offerings (Collier and Meyer, 1998). This should include identification of fail points and appropriate ways to deal with service recovery, such as "script dialogues for difficult situations, train staff thoroughly in communication and response techniques, establish mechanisms that always responds, records, and confirm all customer's instructions, etc." (Shostack, 1994; Cook *et al.*, 2002).

The above discussion has highlighted sample managerial indications regarding the influence of significant attributes that characterize (and classify) services, to aggregate processes of the service life cycle. It is noted, however, that SAPM can be specified for the reassessment of a particular service or for the design of a new service.

Chapter 4. Quality at the source and the impact of failures in service operations[13]

4.1 Introduction

Lean practices have focused heavily on the reduction of variability, especially variability stemming from improper operating conditions or policies. In service operations however, as already mentioned, variability is inherent to the process due a) to the participation of the customer in service production, and b) to the strong dependency of the service on the server. Variability in services is also related to failures; that is, events or system conditions that prevent the service organization to deliver appropriate quality, speed or flexibility. Managing failures

[13] Most of the work in this chapter has been published in the paper "Assessing the impact of failures in service operations using experimental design with simulation" (Gliatis, Minis, and Lavasa, 2013)

in services – especially in customer and information intensive ones – is quite challenging for a number of reasons related to the unique characteristics of services.

In this Chapter we attempt to address the operational perspective of failures; that is, we attempt to quantify the impact of critical failure parameters on key system performance measures, such as cycle time and work-in-process. We also analyze various operational concepts, or management practices, that service organizations use to address the effects of failures. These include tactical decisions, such as increasing capacity to deal with backlogs, or more fundamental interventions in the structure of the system, such as creating separate routes for handling complaints and failures. In order to analyze the cause-and-effect (or input-output) relationships between failure parameters and performance, we use discrete event simulation and design of experiments.

4.2 Review of the relevant literature

Having reviewed significant results of the service literature, we distinguish three stages in the service life cycle in which failures may arise. The first stage concerns the *design of the service system*, i.e. failures to incorporate into the system design those features that support quality, timeliness, system availability, as well as service variety. It is believed that such weaknesses are intrinsic causes of the inflexibility of the service system to cope with the variability inherent in services. For instance, Harvey (1997) provides examples of fragmented processes and rigid workflow systems or technologies that fail to incorporate alternative delivery paths for handling exceptions, or changes in market conditions. Several authors (Harvey, 1997; Apte, Beath and Goh, 1999; Seddon and Caulkin 2007; Piercy and Rich, 2009) discussed the impact of the organizational design on the performance of service delivery. For example, in a functional organization it may be challenging to guide the customer inside the delivery system, or to assign responsibility towards the client between functions; this has an adverse impact on errors and waiting times.

The second stage is related to the *management of the service system*, i.e. failures occurring as the result of management's tactical and short term decisions, such as staffing, synchronization and performance management. For example, Harvey (1989) argues that long waiting times in services may be attributed to structural deficiencies, that is the way professionals are organized and managed. He proposed a series of alternatives to address the issue such as the frequent rebalancing of the process. Furthermore, Oliva (2001) and Oliva and Sterman (2001) argue that quality erosion and loss of revenue in services may be related to management decisions regarding effort allocation, capacity management, overtime, and quality aspirations. Through simulations and field studies they have explored several policies to improve performance and implications for organization design in the service sector. Finally, Piercy and Rich (2009) provided evidence, through case studies in the financial sector, that arbitrary performance measures can reinforce the negative behavior of servers, leading to inferior customer service and increased costs.

The third stage relates to the *service delivery*, i.e. failures occurring during the execution of the service, such as problems in the quality and timeliness of the service. Chase and Stewart (1994) classified related service failures in server and customer errors. Server errors include errors in the task (doing work incorrectly/ not requested/ in the wrong order/ too slowly), the treatment (failure to acknowledge/ listen/ react to the customer), or the tangible aspects of service (physical elements such as incorrect or unclear bills, power outages, etc.); customer errors include errors or omissions caused by customers (failures in the preparation/ encounter/ resolution of the service).

A closer examination of the above insights implies a strong relationship between design and management decisions on the one hand, and the execution of the service on the other. Weaknesses in the design and management of service systems can lead to consistent failure patterns. Although such patterns can be predicted and hence prevented, this is not always the action of choice by managers due to the investments required, or due to existing mindsets. In both cases, we believe that the underlying cause that prevents service managers from addressing the root causes of failures lies primarily in the lack of awareness of their impact on the performance of the system. The impact of service failures and service recovery strategies on an important aspect of the system, customer satisfaction and loyalty, has been extensively discussed in the service literature (Heskett, Jones, Loveman, Sasser, and Schlesinger, 1994; Kelly and Davis, 1994; Spreng, Harrell, and Mackoy, 1995; Tax and Brown, 1998; Hayes and Hill, 1999; Colgate and Norris, 2001; Lewis and Spyrakopoulos, 2001; Weun, Beatty, and Jones, 2004.

The above research has focused mainly on the customer’s view on service quality. In the present work, as already mentioned, we quantify the impact of critical failure parameters on key system performance measures, such as cycle time and work-in-process. We also analyze various operational concepts, or management practices, that service organizations use to address the effects of failures.

4.3 The environment under study and model development

In order to analyze the effects of failures on service operations, we have defined a simple, but typical, service system, which comprises two stages representing front-office and back-office operations (Figure 4.1).

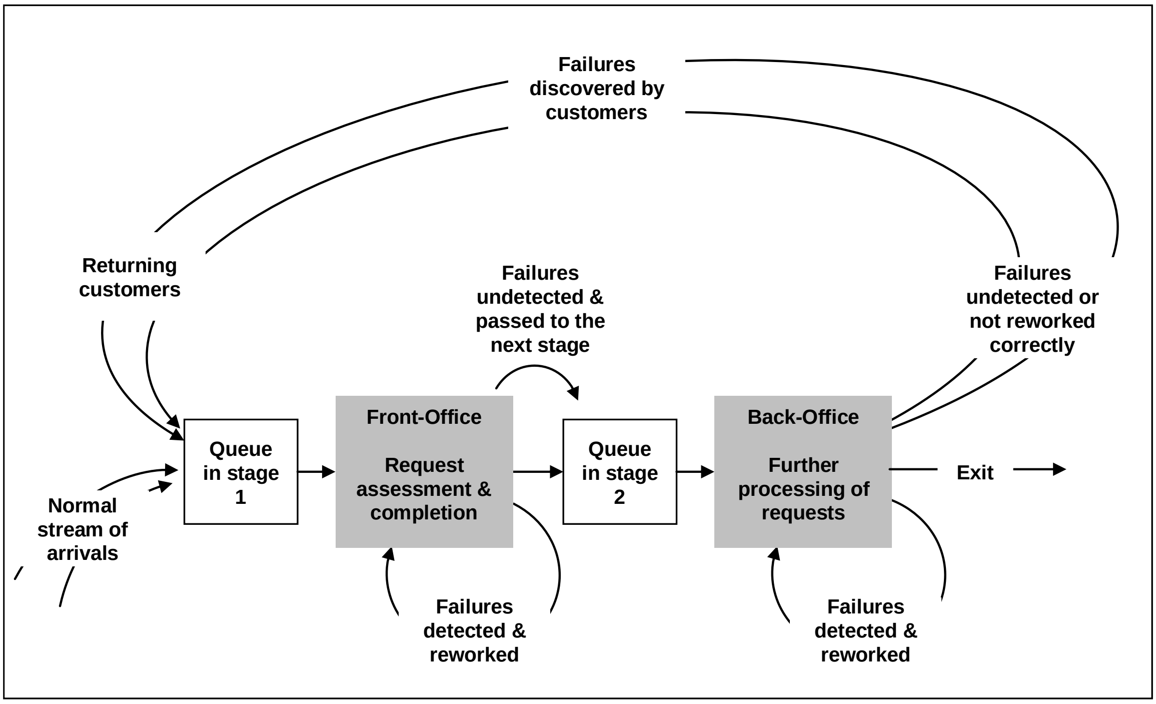


Figure 4.1: The simulated system

For simplicity, the system provides only one type of service. Each stage performs a single process; that is, customers enter the front-office and wait in the initial queue; subsequently, the front-office completes the first stage of the customer requests (jobs), and forwards it to the back-office queue. The back office staff process the semi-finished jobs in sequence, and, upon completion, the jobs are released from the system.

Failures may occur in either stage; if a failure is not detected while the job is in process, then the job will be sent either to the next stage, or exit the system providing the opportunity for the failure to be discovered later by the customer. In this case, the customer will return to the system's initial queue to resubmit the request. If the failure is detected while the job is in process, then it will be reworked. If the failure cannot be reworked, it will lead eventually to a financial loss. Finally, during the rework phase there is the possibility of further failure(s) to occur leading to a repetition of the entire cycle. The tree of the possible outcomes regarding failures and rework is presented in Figure 4.2.

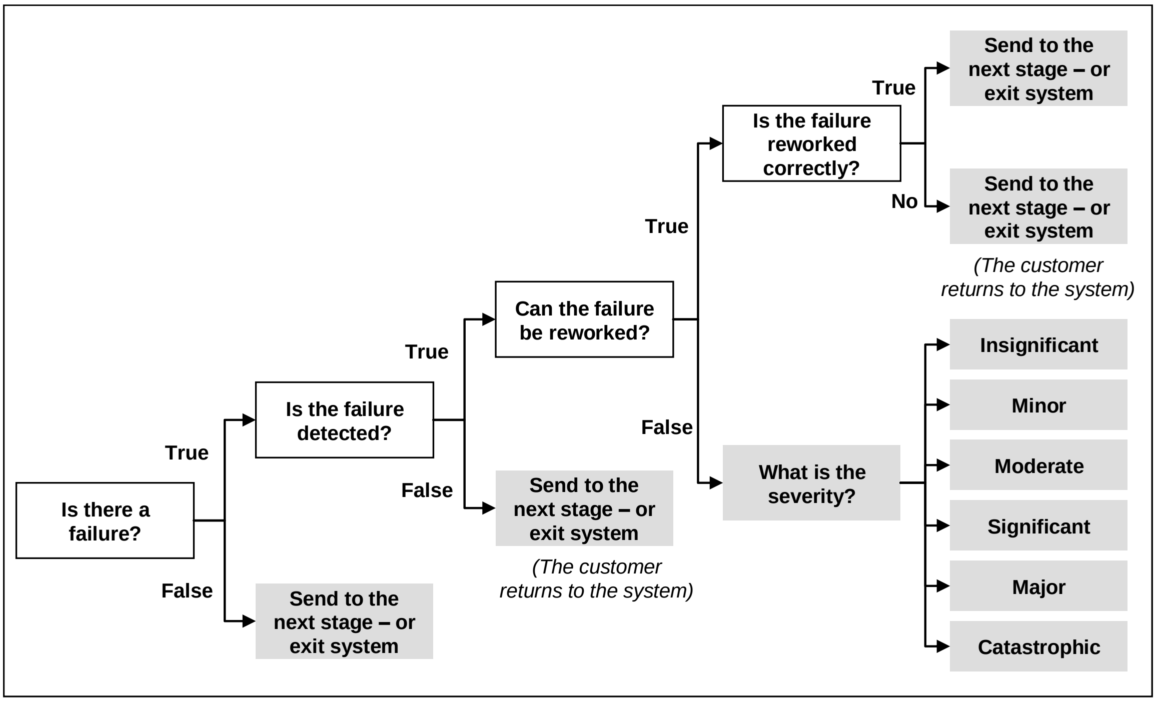


Figure 4.2: Tree of possible outcomes for failures and rework

While simple, this is a typical situation encountered in many service organizations. Furthermore, analyzing this two-stage system may provide insights to be used in the analysis of more generalized (n-stage) systems (Gopalan and Kannan, 1994). The nominal system used for the experimental study is characterized by the parameters presented in Table 4.1.

Table 4.1: Parameters and assumptions of the nominal service model

Parameters		**Description**
Entities	Requests (Jobs)	• All customer requests (jobs) are of the same type and are treated in the same way
	Servers	• Two types of servers exist, the Front-Office servers and the Back-office Servers. In our example, each of the two stages comprises 4 parallel servers with the same skills each
Events	Arrival	• The arrival process is described by a Poisson process with a mean inter-arrival time of 3 min. (no batch arrivals)
	Departure	• The job departs from the system as soon as processing by the back office is completed
Activities	Front Office – processing time	• It follows a normal distribution with mean of 7 min and standard deviation of 3,5 min
	Back Office – Processing time	• Same as above
		• There is zero transfer delay between the Front Office process and the buffer of the Back Office process
Queues	Queue discipline	• There is a single queue at every stage with infinite capacity. Each customer request may be processed by any of the servers in each stage (the first available one)

Parameters		Description
	Queue configuration	• A First-Come-First-Served rule is used to manage the queues. However, priority is given to failures detected in-process, which are reworked
Failure and Rework - parameters	Failure Rate	• The probability of failure (Failure Rate); is identical for each stage, but the failures of the two stages are independent • Each server inspects his/her own work and cannot detect failures occurred in previous stages
	Failure to Detect Rate	• This is related to the probability of not detecting the failure in-process. This probability is identical for both stages • All failures are detected; either immediately upon completion of a process, or after a period of time by the customer. This period of time is described by an Exponential distribution with a mean of 2 days
	Inability to Rework Rate	• This is related to the probability of not been able to rework every defective job, and is identical for both stages
	Incorrect Rework Rate	• This is related to the probability of not reworking properly an identified failure, and is identical for both stages
	Severity of failures	• Each failure that cannot be reworked is classified to one of six categories as related to financial losses (Table 4.2)
	Rework processing time	• The rework process time in both stages follows the normal distribution with mean 7 min and standard deviation 3.5 min
	Rework method	• Two rework methods are used (Rework Stage): Single Stage i.e. the defective request is reprocessed by the entire value stream, and Multiple Stage, i.e. the defective request is only processed by the stage responsible for the failure
System conditions	System state	• The system is in steady state and balanced (with all servers in a stage having the same capacity, and the same process time parameters)
	Working hours and replication length	• Replication length is 30 days with 8 hour shifts per day

The degree of impact of a failure on the operation of the system has been expressed in financial terms (economic losses for the company). The different levels of severity, their impact as well as the distribution of failures within these levels are given in Table 4.2. These figures have been derived from a European financial institution in the post-trade services.

Table 4.2: Severity of failures, financial impact and distribution

Severity Level	Financial Impact (€)	Failure Distribution
Insignificant	500	89.32%
Minor	5,000	8.93%
Moderate	30,000	1.49%
Significant	200,000	0.22%
Major	1,500,000	0.03%
Catastrophic	10,000,000	0.01%

4.4 Experimental design

In order to analyze the effects of failures in the above service system, we used the Design of Experiments (DOE) method (Montgomery, 2005). Specifically we identified those critical inputs that characterize failures and analyzed their effects on the performance (outputs) of the system.

4.4.1 Factors (inputs)

As inputs, we have selected factors that are relevant to services and are considered important in the existing literature on rework (Robinson *et al.*, 1990; Agnihothri and Kenett, 1995; Zargar, 1995; Hopp and Spearman, 2001; Flapper *et al.*, 2002; Li, 2004; Sha and Hsu, 2004; Li *et al.*, 2008). These factors are the following:

- *Failure rate*: The probability of a failure to occur
- *Failure to detect rate*: The probability of not detecting a failure while in process
- *Inability to rework rate*: The probability that a failure cannot be reworked
- *Incorrect rework rate*: The probability of the rework process to lead to a new failure,
- *Rework stage*, i.e. whether a job to be reworked is reprocessed by the entire value stream again (single stage) or it is only reprocessed by the stage in which the failure occurred (multiple), as defined by Flapper *et al.* (2002).

For each of these factors (inputs) we have set two levels as presented in Table 4.3.

Table 4.3: Factors and levels for the full factorial experiment

Factors	Level	
	Low	High
Failure rate	5%	15%
Failure to Detect Rate	15%	35%
Inability to Rework Rate	5%	15%
Incorrect Rework Rate	5%	15%
Rework stage	Multiple	Single

For the failure rate we have selected rather conservative levels, considering other references that indicate a failure rate of 30%-40% in certain service industries (Seddon, 2005). The same values have been used for the (a) inability to rework rate and (b) the incorrect rework rate, considering the fact that usually different servers might be called to rework a failure. The levels of the failure to detect rate were set at higher levels, reflecting the difficulty to detect failures immediately after their occurrence.

4.4.2 Experimental outputs

Table 4.4 lists the six performance measures we have used to assess the effects of the above inputs on the performance of the service system.

Table 4.4: Experimental outputs

Performance Measures	Description
Cycle Time	• The average time a job spends in the system. It is the average of the sum of the processing, waiting, and rework times
Work-in-Process	• The average number of jobs in the system, either being processed or waiting to be processed
Queue Waiting Time	• The average waiting time of a job in both queues of the system
Utilization	• The average time that the servers are busy over their total available time (cumulative capacity)
Customer Satisfaction	• The ratio of the time spent for the job to be processed for the first time, over the total time required to complete the job. For each job this ratio is: $$\frac{PT}{\sum_{i=1}^{n}(QT_i + RT_i) + \sum_{i=1}^{n}(T_p) + PT} \quad (4.1)$$ where: ○ PT is the time the job spends in process for the first time (sum over both stages) ○ QT_i: is the time the request spends in waiting during visit i ○ RT_i: is the rework time of a job during its i-th visit, if this job needs to be reprocessed (RT_1=0). ○ T_P is the effort, expressed as a constant time, required for the customer to visit/contact the service system.
Financial Impact	• The average financial losses (in Euro), for failures that cannot be reworked. The severity of the financial losses is defined in Table 4.2

4.4.3 System modeling

Based on the above factors and levels we have designed a 2^5 full factorial experiment with 32 different combinations of the experimental factors. For each combination, two experimental runs were conducted (64 runs in total), in order to extract information on the variability of the results that is required to conduct Analysis of Variance (ANOVA). Each experimental run spanned thirty simulated days during eight-hour shifts. The service system was modeled using the Arena 11.0 simulation software (Kelton, 2000; Kelton, Sadowski, and Sturrock, 2007). The DOE analysis was performed using the Minitab 15 statistical software.

4.5 Results and discussion

4.5.1 Experimental findings

4.5.1.1 Factors and statistical significance

In the analysis, we assessed the statistical significance of the input factors and their interactions by examining their P-values with a level of significance set to α=0.05. We also developed Normal Probability Plots and Pareto Charts to visualize the significance of the effects of the inputs on the system outputs, as well as residual plots to validate the assumptions of normality that underpin the experimental procedure. Finally, the main effects and the significant interactions were quantified. The entire statistical analysis for the cycle time is presented in Appendix C:. A summary of the significant factors and two factor interactions for each output (performance measure) is presented in Table 4.5.

Table 4.5: Factors and statistical significance at α=0.05 (p-value)

	Term	Cycle Time	WIP	Queue Waiting Time	Utiliza-tion	Customer Satisfa-ction	Financial Impact
Main Effects	A: Failure Rate	√	√	√	√	√	√
	B: Failure to Detect Rate	√	√	√		√	
	C: Inability to Rework Rate	√	√	√		√	√
	D: Incorrect Rework Rate					√	
	E: Rework Stage	√	√	√	√	√	
2–Way Interactions	A*B	√	√	√		√	
	A*C	√	√	√			√
	A*D						
	A*E	√	√	√	√	√	
	B*C						
	B*D						
	B*E	√	√	√	√	√	
	C*D						
	C*E	√	√	√		√	√
	D*E						

In reviewing the results, and especially the size of the input effects (Appendix C:), certain important conclusions can be drawn regarding the impact of the various failure and rework factors on system performance:

- Amongst all factors, *failure rate* has the strongest impact (highest effect value) in almost all performance measures (except financial losses, which is impacted more significantly by the input *inability to rework rate*). Thus, failures that lead to rework degrade significantly the performance of the nominal service system.
- The impact of *failure rate* on performance is more pronounced when the *single rework stage is applied*: thus, the higher the number of failures and the longer it takes to correct them, the worst is the performance of the system.
- Financial losses are impacted mainly by the inputs *inability to rework* and *failure rate*, i.e. the higher the probability of a mistake being irreversible, combined with increased failures, increases significantly the related financial losses.

- The *failure to detect rate* effects all performance measures of the system (especially customer satisfaction and financial impact), although at a lesser degree; i.e. the sooner the failure is detected the better for all aspects of performance.
- Cycle Time, Queue Waiting Time, WIP, Utilization, and Customer Satisfaction are not affected by *failure to detect rate, inability to rework rate* and *incorrect rework rate* when the *multiple stage rework* practice is applied, i.e. the impact of failures is reduced if the failure is identified and corrected at the source.

From these experimental results we can deduce some important implications for management: Failures degrade all aspects of performance of a service system. Thus designing out failures, that is, taking actions to prevent failures from occurring in the first place, is central to improving the performance of service systems. Failures may be compensated by some combination of time, capacity and money; if managers don't invest enough time and resources to reduce failures, the system will feel the impact at a later stage through increased cycle times, long queues, wasted capacity, poor customer service and eventually financial losses (Hopp and Spearman, 2001).

Additionally, early detection, and especially awareness, of failures is key for performance. From an operational point of view, it prevents customers from returning to the system, increasing the normal stream of arrivals, and causing further delays. Finally, the comparison between the two rework methods reveals that the effect of a failure on the system's performance is reduced, if the failure can be traced and corrected at the stage in which it occurred. This implies that the service organization should have systems in place that can support the effective and timely recovery from failures. Such practices include a clear view on the potential failures and the risks associated with them, realistic contingency plans, as well as clear, end-to-end ownership to deal with failures when and where they occur.

4.5.1.2 Study of typical management practices used to address failures

Recognizing the significance of failures in system performance, management has developed several practices to address this issue. We used simulation to assess the effectiveness of three relevant management interventions (Table 4.6).

Table 4.6: Management interventions to address the impact of failures

Practice	Description
Base Case	This is the reference experiment in which all factors assume their high values (presented in Table 4.3) to reflect a service system being overburdened; the multiple rework method has been selected, since it was considered more realistic in a service setting

Practice	Description
Add Capacity	According to this practice, the capacity of the service system is enhanced by adding new (but less experienced) staff. We have assumed a capacity increase of 25% (1 additional staff member per stage of the service system.) To model the lower level of experience of the new staff, the process time variability has been increased from NORM(7, 3.5) to NORM(7, 7).
Chase Demand	This practice pursues enhanced productivity, by increasing the processing speed to follow the increased demand. In this case, the process time has been decreased by an aggressive 20%; however, the process variability has also been increased from NORM(7, 3.5) to NORM(5.6, 5.6).
Off-line processing of failures	In this management practice a new station has been introduced per system stage for reworking all failures off-line. This results to a nominal capacity increase of 25% (equivalent to an additional staff member per station of the service system) dedicated to address job defects. Again, in order to reflect the lower experience of the new staff members, we assume that the process time variability has been increased from NORM(7, 3.5) to NORM(7, 7).

Table 4.7 summarizes the experimental conditions, as well as the levels of the input factors used for the study of the typical management interventions. The performance of each intervention has been compared with the performance of the base case.

Table 4.7: Parameters of the models used to study management interventions

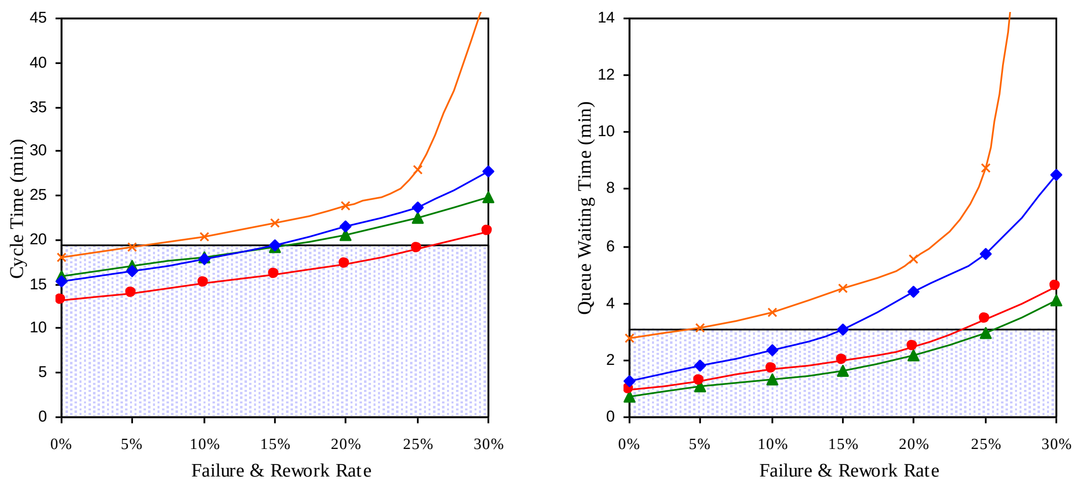
Parameters	Base Case	Add Capacity	Chase Demand	Off-line processing of failures
Arrival rate	1 request every 3 minutes			
Number of Servers	8	10	8	10
Process time (per stage)	NORM(7, 3.5)	NORM(7, 7)	NORM(5.6, 5.6)	NORM(7, 7)
Failure Rate	15%			
Failure to Detect Rate	35%			
Inability to Rework Rate	15%			
Incorrect Rework Rate	15%			
Rework method	Multiple			

The results of this study are presented in Table 4.8, in which we rank the mean values of the performance measures (1st been the best overall value) for the different management practices (at the above failure and rework levels.) These results clarify the trade-offs between the different management practices compared to the base scenario. For instance, if we consider the cycle time and the work-in-progress, the system seems to benefit from the *chase-demand* and *add-capacity* practices, while the *off-line rework* practice appears to have inferior results compared to the *base case*. Similar behavior is observed regarding queue waiting; in this case, however, the highest benefit results from the *add-capacity* practice. Customer satisfaction improves when using the *add-capacity* practice. On the contrary, it deteriorates under the *chase-demand* and *off-line rework* practice. Finally, financial impact and utilization deteriorate for all management practices compared to the *base scenario*.

Table 4.8: Comparison of the management practices for failure and rework rate at 15%

Practice	Base Case		Add Capacity		Chase Demand		Off-line processing of failures	
Performance Measure	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean
Cycle Time (min)	3rd	19.4	2nd	19.2	1st	16.0	4th	22.0
Work-in-Process (units)	3rd	6.5	2nd	6.4	1st	5.3	4th	7.3
Queue Waiting Time (min)	3rd	3.1	1st	1.6	2nd	2.0	4th	4.5
Customer Satisfaction (%)	2nd	61%	1st	66%	3rd	60%	4th	60%
Utilization (%)	1st	67%	2nd	58%	3rd	58%	4th	46%
Financial Impact (€)	1st	95.2	4th	206.8	3rd	175.6	2nd	130.4

A further analysis was conducted to examine the performance of the three management practices under several levels of the failure and rework rate. This analysis indicates that, under certain conditions, a management practice may provide results that are opposite to the original management intentions, if the policy causes an increase to failure and rework levels (Figure 4.3); i.e., the system performance may deteriorate by adopting a new practice when the failure rate rises beyond a certain level.



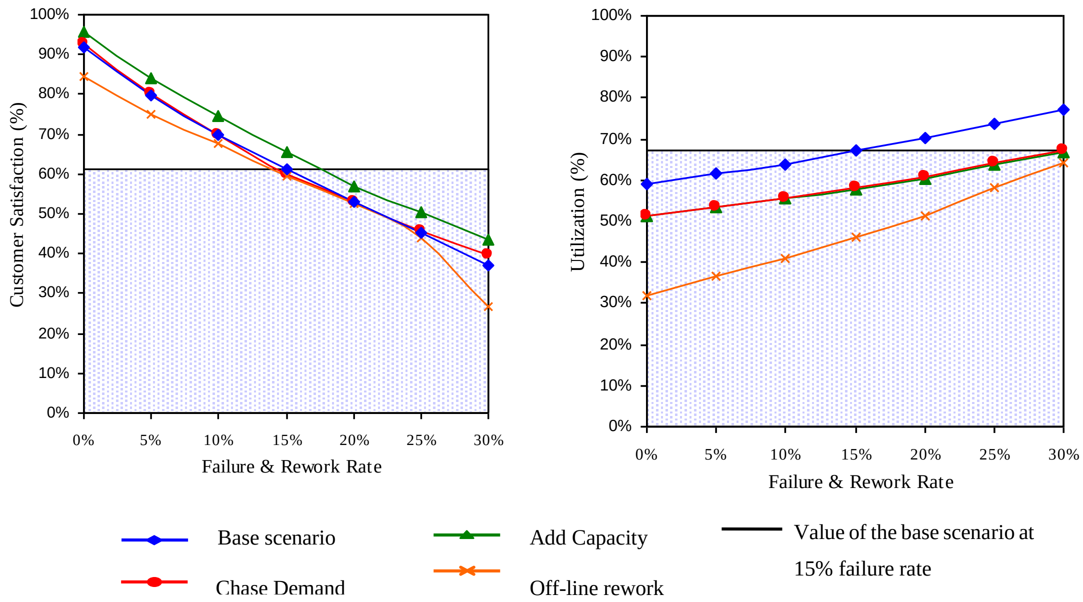


Figure 4.3: Comparison of the management practices for various failure and rework rates

In the case of the *chase-demand* practice for instance, the system seems to benefit in terms of cycle time and queue waiting time. However, if, by adopting the new practice, failures increase beyond 25%, the benefits seem to disappear. Note that the (unintended) increase of the failure rate may occur due to the pressure to increase productivity beyond certain limits; this may degrade the quality of work and, eventually, the performance of the system (Oliva and Sterman, 2001; Piercy and Rich, 2009).

The *add-capacity* practice improves queue waiting and customer satisfaction, while it maintains comparable results to those of the base scenario with respect to cycle time. However, the lower level of experience and productivity of the new staff (resulting to higher failure rates and higher processing time) could offset the benefits from adding capacity, at least in the short term. Thus, if failures increase by adopting this practice beyond 17%, the benefits seem to disappear.

Finally, the *off-line rework* practice exhibits inferior results in all aspects of performance, due to a) the lower levels of staff productivity, and b) the fact that the enhanced capacity has been dedicated to address job defects only.

4.5.2 Case study in the financial services

In order to test the validity of the previous findings, we analyzed the performance of a transaction processing team of a European financial institution. The analysis concerns post-trade services and was conducted during a three-month improvement project. This team manages corporate action events; that is, events initiated by publicly traded companies that may potentially affect the securities (equity or debt) issued by these companies. Since a significant proportion of processing caused by these events is automated (straight-through processing), we focused only on the events that require manual intervention, such as mandatory events. The latter do not require any direct action from the securities holders (apart from internal accounting), thus encompassing less variability. The life cycle of an event comprises two stages similarly to the above simulation model. In the first stage, information for upcoming mandatory events is sent from the financial data vendors (such as Bloomberg and Telekurs) or directly from agents and depositories, and enters electronically in the system's initial queue. Subsequently, this information is validated and then it is distributed electronically to the shareholders and provided to the second stage of the system, in order for the payments to be processed. Upon completion, reports are released from the system to the respective customers.

To collect data for our study, we recorded arrival and processing times during a full week of operation. Furthermore, in order to quantify failure parameters, we selected a sample of archived incoming calls and written queries related to failures and assessed together with the operators, the root causes of each failure and whether the failure was repeated over time.

Our study revealed a high proportion of failures (failure rate equal to 24%) in the processing of the events. A deeper investigation on the root causes of failures highlighted repetitive patterns of failure and rework, leading to low customer satisfaction and financial losses, especially when the team was forced to cope with growing event volumes. The four major causes of failures were identified.

First, when the demand increased during certain days of the month strict deadlines on a daily and hourly basis created significant pressure to the operators. The latter, in order to comply with the workload, were cutting corners or taking shortcuts, i.e. did not take the necessary time to understand the event and avoided skimmed through necessary steps required in the process. This resulted to failures at a later stage.

A second cause of failures was the inferior quality and timeliness of input information; very often the information was sent late by the providers, or contained unnecessary – and even wrong – data. As a result the ability to detect failures was limited (i.e. failure to detect rate equal to 70%).

A third source of failures was the organization and set up of the teams. For example, the process was not balanced since the instruction process (second stage) was taking more time than the information process (first stage). As a result the queue of the second stage was long.

The forth source of failures related to the tangible software applications used. For instance, several applications did not generate compliant reporting, leading to client queries. The complete set of the observations and assumptions is presented in Appendix B.

We used the parameters of Appendix B, to construct the corresponding simulation model (much as the one discussed in the previous Sections). We ran the model under the measured inputs, and compared its outputs to the outputs of the actual system. Table 4.9 compares the measurements (observations) with the simulation results.

Table 4.9: Actual vs. simulated results for various parameters

Parameter	Simulated	Actual
Monthly Throughput (events)	1375	1366
Cycle Time (min)	57.0	59.0
Work-in-Process (events)	5.7	NA
Queue Waiting Time (min)	8.6	8.0
Customer Satisfaction (%)	45.5	NA
Utilization (%)	56.9	NA
Financial Impact (€)	277.4	NA

Having established the fidelity of the model, and of the discrete event simulation, we analyzed the performance of the three management practices discussed above to address the impact of failures. Table 4.10 presents the parameters of the simulation model used to study management practices.

Table 4.10: Parameters of the models used to study management interventions

Parameters	Base Case	Add Capacity	Chase Demand	Off-line processing of failures
Arrival rate	1 request every 10 minutes			
Number of Servers	8	10	8	10
Process time (Information)	LOGN(14.9,9)	LOGN(17.9,10.8)	LOGN(11.9,11.9)	LOGN(17.9,10.8)
Process time (Instruction)	LOGN(19.8,8.5)	LOGN(23.8,10.2)	LOGN(15.8,15.8)	LOGN(23.8,10.2)
Failure Rate	24%			
Failure to Detect Rate	70%			
Inability to Rework Rate	3%			
Incorrect Rework Rate	50%			

Parameters	Base Case	Add Capacity	Chase Demand	Off-line processing of failures
Rework method	Multiple			

The results of this study are presented in Table 4.11. In terms of cycle time and work-in-progress, the system seems to benefit from the *chase-demand* practice, while the *add capacity* and *off-line rework* practices appear to have inferior results compared to the base case. Similar behavior is observed regarding queue waiting. Customer satisfaction improves when using the *add-capacity* practice. On the contrary, it deteriorates under the *chase-demand* and *off-line rework* practice.

Table 4.11: Comparison of the management practices for failure and rework rate at 24%

Practice / Performance Measure	Base Case		Add Capacity		Chase Demand		Off-line processing of failures	
	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean
Cycle Time (min)	2nd	57.0	3rd	64.1	1st	42.4	4th	89.2
Work-in-Process (units)	2nd	5.7	3rd	6.4	1st	4.3	4th	9.3
Queue Waiting Time (min)	3rd	8.6	2nd	5.6	1st	3.7	4th	32.9
Customer Satisfaction (%)	2nd	45.5	1st	50.0	3rd	44.6	4th	39.9
Utilization (%)	1st	56.9	2nd	55.0	4th	45.7	3rd	49.8
Financial Impact (€)	2nd	277.4	3rd	291.3	1st	242.0	4th	355.8

A final analysis was conducted to examine the performance of the three management practices under several levels of the failure and rework rate. This analysis verifies the existence of the previously observed failure thresholds, above which the management practices deteriorate system performance. In the case of the *chase-demand* practice for instance, the system seems to benefit in all performance measures. However, if failures increase by adopting the new practice beyond 40%, the benefits seem to disappear. The *add-capacity* practice improves queue waiting, customer satisfaction and utilization, while it presents results inferior to the *base scenario* with respect to cycle time. Finally, the *off-line rework* practice exhibits inferior results in all aspects of performance, due to a) the lower levels of staff productivity, and b) the fact that the enhanced capacity has been dedicated to address job defects only.

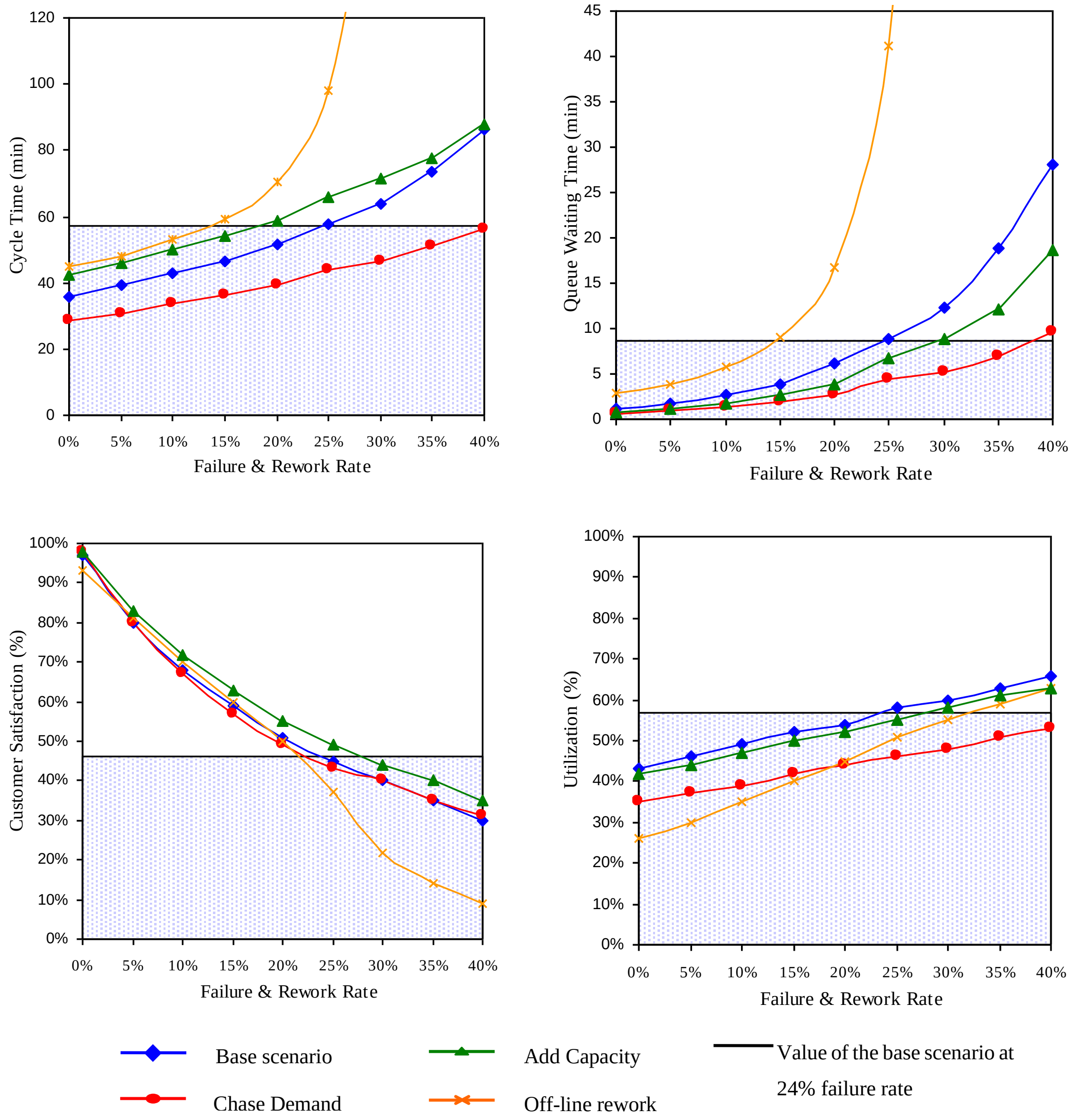


Figure 4.4: Comparison of the management practices for various failure and rework rates - case study

Chapter 5. Cellular work structures and appropriateness in service operations[14]

5.1 Introduction

Over the last thirty years, several concepts have been transplanted from manufacturing to service operations, especially with the emergence of LM and the Toyota production system. As such, cellular operations, one of the most important components of lean, have been adopted by certain areas of the service sector, primarily healthcare.

Cellular manufacturing decouples a functionally organized production system into semi-autonomous sub-units dedicated to the production of items with similar design and processing

[14] Most of the work in this chapter has been published in the paper "Appropriateness of cellular operations in information intensive services" (Gliatis and Minis, 2017)

attributes (Hyer and Brown, 1999). Specifically, a cell satisfies the following design principles (Hyer and Brown, 1999; Hyer, Wemmerlöv, and Morris, 2009):

- *Similarity of the objects processed* in terms of process (similar steps and flows - routings) that minimize the need to spend time on set-up changes. An object can be a service line (or product) identifiable by customers, a market segment, or some combination of the two.
- *Autonomy and responsibility in completing an object*. A cell is responsible for completing as much as possible of the service line (product or part), using diversified resources (operators and equipment).
- *Flexibility of resources*. A cell typically is composed of three to seven operators (no more than ten), each assigned to a primary task but capable of performing a series of additional tasks to complete the service.
- *Time dependency of cell activities*. There should be little delay between the completion of a job and the start of the next, minimizing non value added time (e.g. transfer and waiting times) between dependent tasks.
- *Information dependency of cell activities and the resources performing them*. Cell resources have access to complete and accurate information about the activities within the cell, availability of resources, a common language, accessible visual controls, and whole-task understanding.
- *Proximity of resources*. Cell resources and family-dedicated equipment are located in close proximity, and within clear physical boundaries. Furthermore, they are arranged within the cell such that it reflects the dominant flow pattern of work to minimize distance.

Past research in cellular manufacturing has reported substantial benefits from the adoption of cells (e.g. reduction in work-in-process inventory, setup time, throughput time), provided that three conditions are met.

The first condition concerns the *initial state of the system*, as expressed via key operational parameters (such as utilization, batch size, setup and process time and variability), and the *extent* that this state may be improved by the cellular transformation to overcome reduced efficiencies stemming from the loss of *pooling synergy*. The latter is a direct result of assigning to individual cells the resources previously shared in the functional structure, and thus distributing the queue of the latter to several cell queues (Johnson and Wemmerlöv, 1996; Shambu et al., 1996; Agarwal and Sarkis, 1998; Assad et al., 2003). The second condition concerns the *dynamics of the demand*, i.e. cellular structures perform better in environments in which the *demand is steady* (Garza and Smunt, 1991; Suresh and Meredith, 1994). The third condition relates to the ability of the firm to properly manage certain *transition challenges*, including: *technical challenges* e.g. physical formation of cells and the necessary planning (Wemmerlöv and Johnson, 1997; Johnson and Wemmerlöv, 2004; Chakravorty and Hales, 2008), *financial challenges* e.g. costs of acquiring new work centers or relocating existing ones (Johnson and Wemmerlöv, 2004;), and *human-related challenges* e.g. cultural barriers and resistance to change, training, change management (Bidanda et al., 2005; Chakravorty and Hales, 2008).

Recent research highlights the need to a) apply the various clustering approaches to more realistic situations e.g. for managing exceptions (Hameri, 2011) and dynamic conditions in areas such as demand mix, operators, and equipment (Ruiz-Torres and Mahmoodi, 2007), and b) develop full-system design software packages (Papaioannou and Wilson, 2010; Askin, 2013).

Regarding service systems, although significant benefits have been reported from the adoption of cells in some service environments (Swank, 2003; Pagell and Melnyk, 2004; Hameri, 2011), related research in services is rather limited compared to manufacturing. Furthermore, most services face common challenges not addressed in manufacturing, such as the high customer involvement and server dependence during service delivery. Hence, transformations from functional to cellular arrangements in service systems cannot rely solely on the related work performed in manufacturing.

The current work investigates the appropriateness of cellular operations in services and addresses two important areas that have not been examined in the service literature in the context of cellular operations. The first concerns the impact of servers (operators) on system performance, and the second the efficiencies that should be reached as a result of the transformation to the cellular structure in order to offset the loss of the pooling synergy, which is intrinsic in a functional structure. To address these areas, we identify important service-specific factors, which, although relate to the realities of the environment under study, are typical in many other service systems. We use these factors to perform systematic experiments using simulation in order to study the impact of each factor on the performance of both functional and cellular arrangements. We employ past research (Kc and Terwiesch, 2009) to model the behavior of operators and use field data and interviews with managers and employees to build and validate model parameters and results.

5.2 Review of the relevant literature: cellular operations in services

Cellular operations in the service sector have been studied mainly in healthcare through the concepts of service-product line structure and the pioneering concept of the *focused factory* (originally proposed by Skinner, 1974). According to these concepts, specialized units focus on few operations to reduce complexity and gain efficiency through exploiting similarities in how information is processed and how customers (patients) are served (Heskett, 2002; Hyer *et al.*, 2009).

Yet past research in healthcare applications shows mixed results. For instance, there are studies associating product line structures with reduced professional development and reduced job satisfaction (Young *et al.*, 2004), or longer service duration and higher costs (Byrne *et al.*, 2004; Carey *et al.*, 2008). One the other hand, other studies, including more recent ones, present significant improvements, including lower mortality rates (Dobson *et al.*, 2003; Kc and Terwiesch, 2011), reduced patient length of stay (Malakooti *et al.*,2004; Pagell and Melnyk, 2004, Hyer *et al.*, 2009; Kc and Terwiesch, 2011), and reduced costs (Dobson *et al.*, 2003).

In other service sectors, research has been limited. In financial services, one of the early empirical applications reported by Swank (2003) concerns an insurance company that transformed its structure from traditional functional departments to cells based on process complexity. Another empirical application in this sector is reported by Hameri (2011). In this case, production flow analysis is used to identify patterns in the flow of claims through the company's back-office and cluster its resources to cells. Durmusoglu and Kulak (2008) developed a methodology for designing office cells using axiomatic design principles. They applied the methodology for cell formation in a group of four companies managing loyalty campaigns for banks. These studies reported significant reduction in lead time and work-in-process (in some cases up to 77%), lower process variability and higher employee satisfaction.

In summary, research suggests that service providers should address challenges that are *common* to those encountered in cellular manufacturing, as well as challenges that are *unique* to services. In terms of challenges common to manufacturing, the efficiencies that offset the loss of pooling synergy, demand stability, and the need to address technical and human-related challenges need to be taken into account when service systems transition to cellular operations (see also Section 5.1).

The latter two challenges have already been investigated in past research, while the first challenge, i.e. the *efficiencies necessary to offset pooling synergies*, this has not been examined thoroughly in the context of services and represents the *first* contribution of this work. Specifically, we investigate setup in services and the impact of reducing such setups by cellular arrangements. Note that the typical advantage of such arrangements is attributed to setup reduction, which stems from grouping “objects” with similar characteristics. These “objects” may be customer types (Pagell and Melnyk, 2004), service (request) types (Malakooti *et al.*, 2004; Hameri, 2011), or a combination of the two (Swank, 2003). Obviously, the criteria to group “objects” in cells will be industry- and company-specific. Therefore, to investigate the effects of setup reduction we take into account two factors that are generic and relevant to most service systems, i.e. setup efficiencies stemming from a) grouping similar activities into cells, and b) releasing similar jobs in batches into the system.

Regarding *demand stability*, market-mix changes typically result in workload imbalances, which are more pronounced in the cellular structure. In this structure, resources are dedicated to certain service groups configured to address the nominal demand mix, in contrast to the traditional functional structure in which the load of all service groups is shared by all resources in a department (Garza and Smunt, 1991; Johnson and Wemmerlöv, 1996). To address this challenge, service organizations may need to apply additional practices to overcome the inflexibility of cellular operations in market-mix changes, such as the establishment of floating teams that can pick up extra load, demand management, and the frequent reconfiguration of resource grouping (Pagell and Melnyk, 2004).

Regarding *technical challenges*, services are less dependent on capital equipment and, thus, it is easier and less costly to change grouping in order to respond to product-mix changes (Pagell and Melnyk, 2004; Hameri, 2011). Regarding *human-related* challenges, in a cellular environment critical aspects of professional work, such as approach, judgment, and pace, are made visible and may be subject to peer pressure (Harvey, 1989). As a consequence, advocates of professional autonomy are likely to resist change, since their core belief is that autonomy is central to ensuring quality, innovative problem solving, as well as professional development and satisfaction (Young *et al.*, 2004). It is noted that management is also likely to be affected in mitigating possible conflicts between professionals of different expertise (Harvey, 1989).

In terms of the unique characteristics of services, as already mentioned, two challenges relate to service systems transitioning to cellular operations. The first refers to the high *customer involvement* during service delivery, and the second to the *impact of servers* (operators) on system performance. The first has already been investigated in past research, while the latter has not been examined in the context of cellular operations and represent the *second* contribution of this work.

In particular, consider cases in which the customer actively participates in the creation of the service, or the customer is physically present during service delivery (e.g. healthcare). The introduction of cellular operations in this type of environment may negatively affect customer experience in two ways. First, the customer may perceive that the service lasts longer. In a cellular structure, although the total time in the system is likely to be shorter, the initial waiting period prior to first contact may be longer; this latter fact is typically perceived negatively by customers who are less tolerant in waiting prior to initiating system operations (Harvey, 1989; Pagell and Melnyk, 2004). Secondly, the customer might have to contact multiple cells in order to address a wide variety of needs. This may be perceived as inefficiency, since the customer may move to another line, wait her/his turn, initiate a new contact, identify her/himself, etc. (Harvey, 1997).

Regarding the impact of operators on system performance, the current study focuses on three aspects through which the behavior of professional actors (operators in this case) manifests itself and influences service systems performance. These are the way the operators react to changes in system's workload and overwork, their flexibility in terms of array of tasks they can perform and the way they interact with each other. In particular, first, we examine the impact of changes in operator processing speed and output quality as a function of operator workload and overwork. These changes have been documented in the literature (Oliva and Stearman, 2001; Hopp *et al.*, 2007; Kc and Terwiesch, 2009), but have not been considered in cellular studies, even though operators play a major role in service delivery and are expected to behave differently than machines. The second aspect under study is operator flexibility (multi-skilling), which may be a strategic advantage in server-dependent systems. This issue has been studied mainly in manufacturing (Ruiz-Torres and Mahmoodi, 2007). The third aspect in this area concerns operator interactions. Specifically, we investigate the impact of reducing inter-unit interactions by integrating operators into cells. Very few studies have investigated this topic in cellular arrangements (Swank, 2003).

5.3 The information intensive environment under study and its model development

The environment under study comprises a back-office operation that processes corporate action events - that is, events initiated by publicly traded companies that may potentially affect securities (equity or debt) issued by these companies - and customer queries related to corporate actions. The system processes two types of corporate actions, *mandatory* and *elective*. The former involve changes in security characteristics imposed to security holders by the issuing company (e.g. name changes). The latter offer the possibility to security holders to choose between several options related to the corporate action (e.g. optional dividend). The lifecycle of an event comprises three stages:

- *information,* i.e. collection and validation of information on corporate actions from financial data providers (e.g. Bloomberg), and announcement of these events in the company's information systems and website
- *instruction,* i.e. following up customers and executing their instructions (applicable only to elective events)
- *payment,* i.e. calculation of final entitlements and execution of payments.

The system serves customers in different markets, clustered in three groups (A, B and C) based on common characteristics (e.g. time zone, operating rules), and is characterized by high variability in demand, peaking during a certain period (April-June).

In the following Sections, we describe the functional and cellular structures, respectively. The existing system is organized according to the functional structure. The configuration of the cellular structure presented below prevailed amongst several options, since it addressed most cell formation criteria (Hyer *et al.*, 2009).

5.3.1 Main process flows in the functional structure

The functional structure comprises four units: information-processing, order-processing (executing both instructions and payments), call center, and investigation (see also Appendix D, Figure D.1a). Figure 5.1 presents the process flows for corporate action events (stream I) and the related customer queries (stream II).

At every stage, information for events is processed by the operators, and, once completed, it is forwarded to the successive controllers for validating the quality of the information. If an error is discovered while the job is in process, then it is sent back to the operator to be reworked. When the information is passed to the next stage post the controllers, the operator from the downstream unit validates the quality of the output. In case clarifications are needed or errors are detected, the job is sent back for rework to the initial stage, i.e. to the operators of the information-processing unit.

The *probability to rework a job* in this system is considered high and ranges between 20-40%. This has been highlighted during our interviews with operators and their management as one of the most important issues in the current setting. For example, during busy periods, the operators in order to manage workload accelerate their pace or skip over necessary tasks (e.g. reconciliation), "passing the ball" to others. As a result, they have to spend time, at a later stage, reworking the same event. We designate this hand-off between operators that leads to rework as *interaction intensity*. It is distinguished in a) intra-unit interactions (points a, b and c in Figure 5.1), i.e. rework that occurs when operators within the same unit interact due to quality issues, and b) inter-unit interactions (points d-h in Figure 5.1), i.e. interactions between operators from different units for the same reasons.

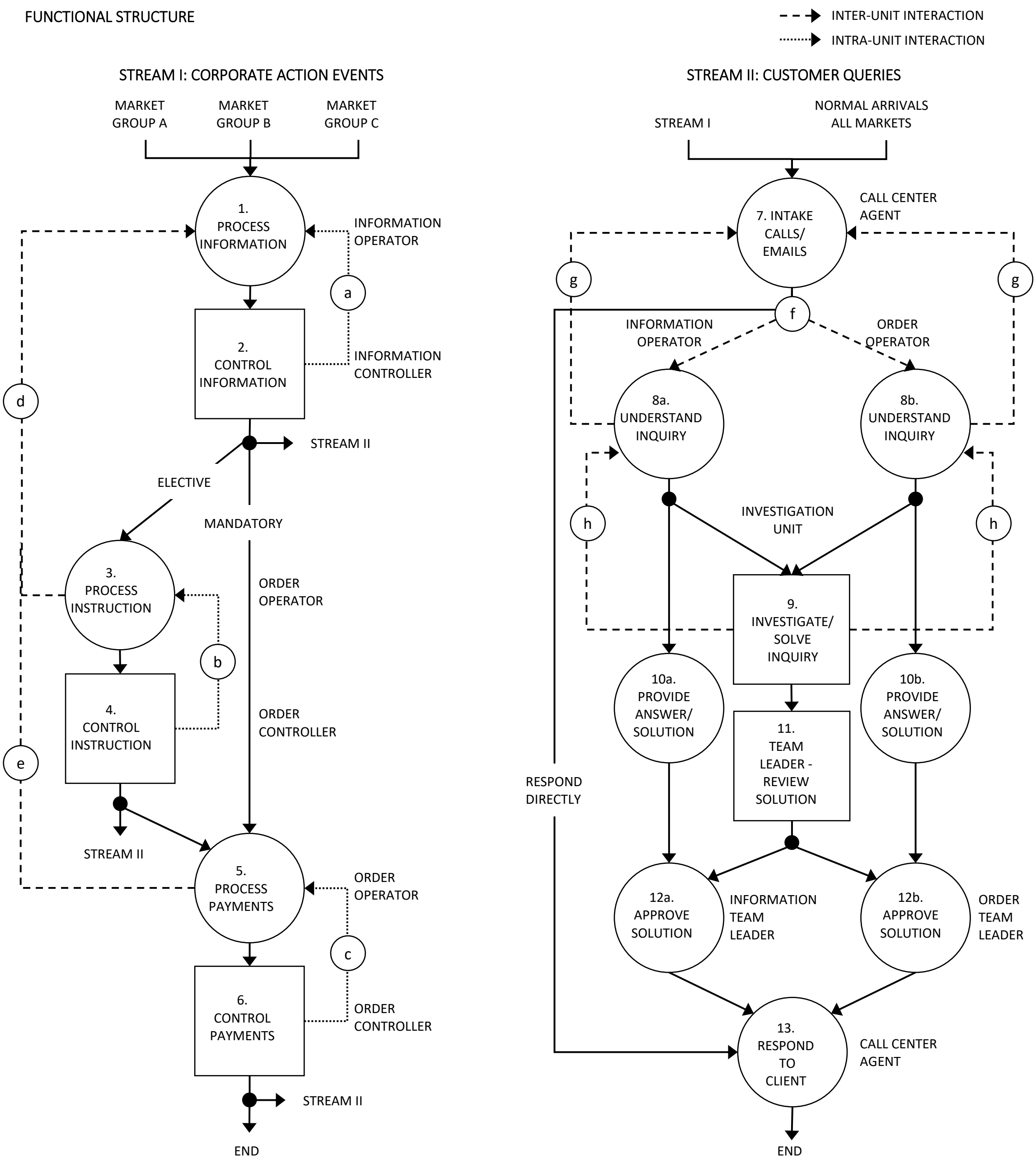


Figure 5.1: Main process flows in the functional structure

Missed errors are typically discovered by customers, which return to the call center with a phone or email query (stream II). Most of the queries (70%) are handled directly by the call center agents. The remaining are typically complex queries or errors which are forwarded to the responsible operational unit for further investigation. These units, in turn, either solve the problem and forward the solution to their team leader for approval, or, in case of complex queries, they forward the case to the investigation unit. The latter focuses exclusively on rework. Once the investigation is completed, the case is forwarded for approval to the investigation team leader and eventually to the respective functional team leader. The final response to the customer is provided by call center agents, since no direct contact with customers is foreseen for the operators.

Another important characteristic of the functional setting is the *setup time*; that is, the preparation time required by an operator in order to start processing a job with characteristics different than those of the previous job. In this case, setup time is required when switching to a job from a different market. Since each market operates under significantly different rules - in some cases up to sixty - the operator needs to set up different configurations prior to commence processing (e.g. different currencies, deadlines, operational definitions, legal rules). We designate this type of setup as *market-setup*. The latter is applicable to the work of both operators and controllers in both streams. Call center agents do not require a market-setup, while investigators face *market* and *job-setup*, since they work with cases both from different markets as well as from different stages of the event lifecycle (job-setup).

5.3.2 Main process flows in the cellular structure

In the cellular structure three units (cells) are formed, each dedicated to a single market group (A, B, or C), in contrast to the functional organization which is based on job specialization (see also Appendix D, Figure D.1b). Each cell includes diversified resources with a wide range of functional expertise (operators, controllers and investigators). In this case, the operators and controllers process both information and order processing jobs. The resources are allocated to each cell proportionally to the demand of the respective market group (40% for Market A and 30% for each of markets B and C). The call center is not affected, since most queries do not require special market expertise and can be answered directly by its agents. Figure 5.2 presents the main process flows for one cell (market group A). Similar flows are relevant to the other two market groups (B and C).

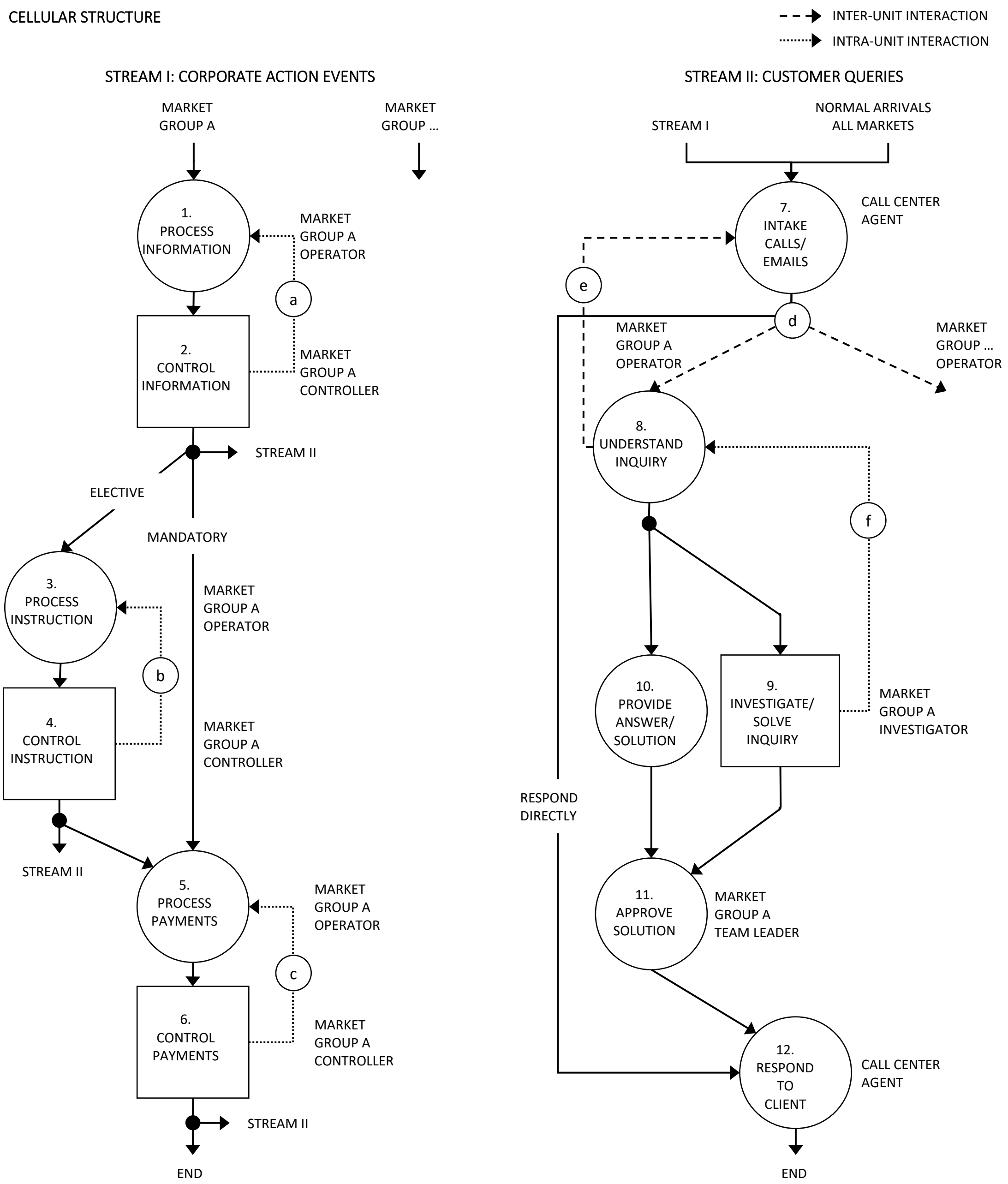


Figure 5.2: Main process flows in the cellular structure (market group A only)

Notably, the conversion from the functional to the cellular structure creates *three queues*, each dedicated to a market group, instead of a *single integrated queue*. The cellular structure increases the autonomy of operators, since they access a broader spectrum of information and multiple system applications to rework entire cases themselves. Consequently, any detected error from previous stages is dealt by the position that identifies it. Thus, hand-over tasks of sending and receiving requests for clarifications and corrections are eliminated. An additional change concerns the elimination of the investigation Team Leader role, as well as the related dual approval layer for customer queries. In this scenario the investigation team leader leads one of the newly formed cells, hence there is no excess labor that penalizes the cellular structure.

Concerning *setup time* in the cellular structure, all jobs processed are assumed to be in the same market, thus no market-setup is required. However, since the operators and controllers execute two different types of jobs (information and order processing) a *job-setup* is required. Specifically, a *job-setup* is necessary every time there is a switch to a different type of job; this switch requires preparation to use different - up to 15 - system applications. It is noted that in the functional structure, as already mentioned, a market-setup is required when switching to a job from a different market, while, job-setup is not required, since the operators are grouped per job type and execute only a limited type of jobs.

Finally, in the cellular structure, and in the event stream, inter-unit interactions do not exist since the information and order processing units are integrated; however, in the queries stream inter-unit interactions are necessary between the call center and the three units-cells (points d and e in Figure 5.2). Concerning intra-unit interactions, they exist in both structures between the operators and the controllers (points a, b and c in Figure 5.1 and Figure 5.2), while in the cellular structure and the queries stream, such interactions are necessary between the processing and investigation operators (point f in Figure 5.2).

5.4 Research approach

To investigate the appropriateness of the cellular versus the functional structures in the service system described above we used experimental design with simulation. To develop the simulation model, we employed the following approach.

First, as model inputs we selected those that a) are directly related to the environment under study, and b) have been identified by relevant literature to be important service factors (Agarwal and Sarkis, 1998; Assad *et al.*, 2003; Swank, 2003; Kc and Terwiesch, 2009). The input levels were selected to cover a range that was deemed reasonable by both the internal transformation team and the system's management team (Head of department and four Team Leaders). The inputs and their levels are discussed in detail in Section 5.4.1. The model outputs include typical system operational performance measures, such as Cycle time, Work-in-process, Queue time and Utilization rate. More details are provided in Section 5.4.2.

Secondly, we employed the work of Kc and Terwiesch (2009) in healthcare operations to develop the relationships for processing time and quality as functions of the system's load and overwork. To determine the parameters of these relationships we conducted interviews with 26 out of the 40 system operators. The model was calibrated with actual data to ensure proper representation of reality. This part of the model and the tuning of its parameters are presented in Section 5.4.3.

Thirdly, we exploited existing process maps to model the functional (baseline) structure of the system. System demand, processing times, and quality rates were obtained from historical data and complemented by direct observations, while missing data were completed based on assumptions provided by experienced staff and their respective team leaders. To validate the cellular structure developed during the transformation project mentioned above, we held thorough discussions with the system's management team and obtained their agreement. The values of the parameters of the simulation model are provided in Section 5.4.4.

Finally, the conclusions of the study were drawn based on statistical analysis that provided the significance of the effects of the selected factors and their interactions on each output of interest.

5.4.1 System inputs (factors)

Five input factors were identified to be important in this setting. These factors and their levels are presented in Table 5.1 and are discussed below, along with the justification of their importance in the system under study.

Table 5.1: Factors and levels for the full factorial experiment

Factors	Levels
State Dependency (STDE)	State Independent (SI), State Dependent (SD)
Flexibility (FLEX)	Single-Skilled (SS), Multi-Skilled (MS)
Setup Reduction (STRE)	0.0, 0.3, 0.6
Interaction Intensity Reduction (IIRE)	0.0, 0.3, 0.6
Setup Ratio (STRA)	0.5, 1.0, 2.0

State Dependency. As stated in the introduction, human behavior is much richer and complex than that of a work center in manufacturing. Indeed, Kc and Terwiesch (2009) have proposed a useful relationship between a) system's load and overwork, and b) the quality and processing time of service tasks. We employed this relationship to model the related behavior of operators and to assess its effect in the performance of the functional or cellular systems. The related factor of the experimental design is the State Dependency (STDE) and includes two levels: state-dependent behavior (SD), which assumes that operators change their processing speed and quality as load and overwork change, and state-independent (SI) behavior, which assumes that processing time and quality remain invariant during operations. The approach followed to model the effects of load and overwork on processing time and quality (SD level), is presented in sub-Section 5.4.3.

Operators' Flexibility. As already mentioned, in the functional structure a market-setup is required when operators switch to a job from a different market, while in the cellular structure a job-setup is required when the operators switch to a different type of job. Since there are more markets (A, B and C) than job types (information and order-processing), the probability of performing a setup is higher in the functional structure. It should also be noted that the mean value of setup time is a fraction (approx. 20%) of the processing time. Apparently, this setup could be avoided if, for instance, in each unit (cell) the market (function) oriented processing was maintained; that is, within the unit (cell) dedicated operators are assigned to specific markets (jobs). However, while the setup time could be reduced, there might be performance degradation due to work imbalances between the operators (as they are dedicated to one type of job or market). To illustrate this trade-off we set two levels. In the first level, the operators are single-skilled (SS), that is, they perform only certain tasks that require particular market (job) skills, reducing the need to perform setup. In the second level the operators are multi-skilled (MS), that is, they perform all market jobs, but they have also to execute setup when switching markets (jobs). This configuration is presented in Figures D.1 and D.2 in Appendix D.

Setup Reduction. In service operations it is possible to control setup requirements through dispatching and proper prioritization rules; that is, a dispatcher groups similar jobs in batches and releases them in order to minimize setups. For a comprehensive review of the various prioritization rules that minimize setups refer to Pickardt and Branke (2012). To reflect the effect of grouping in setup time we introduce the Setup Reduction (STRE) factor. The levels of the latter have been considered to be 0.00, 0.30 and 0.60, indicating the reduction in setup time that can be achieved if prioritization rules were implemented. For example, for a given setup time (2 min), a value of STRE equal to 0.60, indicates that setup time will be 60% less than the initial value (i.e. 0.8 min). STRE is applicable to both structures since prioritization rules can be applied in both.

Interaction Intensity Reduction. Interaction intensity is the probability of having to rework a job received from upstream units. In this case, the mean time to rework has been assumed to be equal to the initial processing time. Interaction Intensity Reduction (IIRE) refers to the potential reduction in the frequency of inter-unit interactions when the structure is converted from functional to cellular. Organizational theory (Young *et al.*, 2004) suggests that by grouping interdependent positions, organizations can decrease information requirements due to improvements in communication, autonomy and common objectives between members operating in the same cell. In our case, by incorporating the investigation unit within the same cell, we expect to increase the cell's responsibility for all potential errors, and the awareness of the causes and effects of problems (Hopp and Spearman, 2001). We have selected to experiment with three levels of IIRE: 0.00, 0.30 and 0.60, where each value indicates the percentage reduction in the frequency of inter-unit interactions (probability of having to rework a job) that can be achieved from the conversion to the cellular structure. For example, assuming that the probability to rework a job received from upstream units is 20%, and applying IIRE equal to 0.60, then the probability to rework will drop to 8% (20% - 0.60×20%). IIRE is applicable only in the cellular structure since functional boundaries do not exist in this structure.

Setup Ratio. As already mentioned, the conversion from the functional to the cellular structure reduces market-setup but introduces a new setup type, the job-setup. To quantify the effect of the conversion to setup, we introduce the Setup Ratio (STRA); that is, the ratio of the job-setup to market-setup. The lower the value of this ratio, the lower is the setup time required in the cellular structure. Three levels were selected for STRA: 0.5, 1 and 2, indicating that job-setup can be one half, equal or twice as long as the market-setup, respectively.

5.4.2 System outputs

From each experimental (simulation) run, we collected the following metrics for both the cellular and functional configurations:

- *Cycle time*, i.e. the mean cycle time value per stage of the system. This is the time elapsed from the moment a job is released into a stage to the moment it exists this stage. The mean value is estimated considering all stages of the system and all jobs processed by it. The stages considered include information, instructions, payments, and customer queries. Cases answered directly by the call center have been excluded
- *Work-in-process*, i.e. the mean number of jobs per stage in the system, either being processed or waiting to be processed. Again the mean value is estimated considering all stages of the system and all jobs processed by it
- *Queue time*, i.e. the mean time a job spends in the initial queue of each stage of the system before being processed. The selection of the specific metric was deemed important based on previous research (Harvey, 1989; Pagell and Melnyk 2004), which

indicates that a potential negative effect of a cellular arrangement in services is the increase of the initial waiting period

- *Utilization rate*, i.e. the time the operators are busy over their total available time throughout the entire system. The mean value of this ratio is estimated considering all stages of the system and all jobs processed by it.

As outputs of the experiment, we considered the percentage difference of the above performance metrics between the functional and cellular structures (Garza and Smunt, 1991). Indicatively, the percentage improvement for the cycle time (PICT) is:

$$PICT = -100 \times \left(\frac{CT_{Cellular} - CT_{Functional}}{CT_{Functional}} \right) \quad \textbf{(5.1)}$$

A value of PICT larger than zero implies that the conversion from the functional to cellular structure results in cycle time improvement. The other three outputs are *PIWIP, PIQT, PIUT* for the work-in-process, queue time, and utilization rate metrics, respectively.

5.4.3 Modeling the effects of load and overwork on quality and processing time

In the current Section we present first the approach followed to model the effects of load and overwork on processing time and quality (SD level). Subsequently, we present the simulation model as well the experiments conducted. According to the work of Kc and Terwiesch (2009) in healthcare operations, load is determined by considering the fraction of number of requests (jobs) to the number of available resources. Below we first discuss the relationship as proposed in their work, and then we apply it to our case.

In the work of Kc and Terwiesch (2009), $LOAD_i$ is defined as the ratio of the number of patients in the hospital unit when patient *i* is admitted divided by the total bed capacity of the unit at the same time. Overwork at the level of the hospital unit is defined using the daily load for *K* days prior to the admission day for patient *i*. Let *d(i)* be the date on which patient *i* is admitted. Then $OVERWORK_{i,K}$ from time *d(i) - K* up to time *d(i)* is defined as:

$$OVERWORK_{i,K} = \frac{1}{N(K,i)} \times \sum_{j=i-N(K,i)}^{i-1} \left[N(K,j) \times \left(LOAD_j - \overline{DAILY\_LOAD_{d(j)}} \right) \right] \quad \textbf{(5.2)}$$

where $\overline{DAILY\_LOAD_{d(j)}}$ is the average load in the unit on the day of admission of patient *j*, and *N(K,i)* is the number of patient arrivals during the last *K* periods up to *d(i)*. It is noted that load assumes only positive or zero values, while overwork may assume any real value, with negative implying that the unit is *underworked*. A large positive value of overwork signifies that the unit has experienced high levels of load.

Considering the above relationship, and actual data for the system described in Section 5.4.4, Table 5.2 presents the load and overwork of the Information-processing unit during a certain time period (March – September). The approach to compute the values of Table 5.2 is described below. A similar approach has been followed for the remaining units (cells).

Table 5.2: Load and overwork for the information-processing unit

Parameters	Mar	Apr	May	Jun	Jul	Aug	Sep
Jobs (N)	3,078	3,187	3,594	2,571	1,753	1,599	1,297
Business Days	23	20	22	20	20	22	22
Available Resources	8	10	10	9	9	8	7
Load (Jobs/Business Days/Resources)	16.7	15.9	16.3	14.3	9.7	9.1	8.4
Load as fraction of Maximum Load	1.00	0.95	0.98	0.85	0.58	0.54	0.50
Load % Difference from Average	29	23	26	10	-25	-30	-35
Overwork	-*	0.203	0.192	0.152	-0.029	-0.210	-0.248

* Overwork value is not calculated since it takes into account the load of the previous month

In Table 5.2, jobs (row 1) is the number of completed corporate actions and customer queries each month. Available resources (row 3) is the number of available operators during each month taking into account absentees and overtime. Load (row 4) is the average number of completed jobs per day per available resource in a given month. Based on Kc and Terwiesch (2009), we express load as a fraction of the maximum load (row 5 of Table 5.2), and estimate the percentage difference of load for each month compared to the average load of the entire period (row 6 of Table 5.2). For example, in April the load is 0.95 and is 23% higher than the average load (0.77) of the entire period.

Overwork is determined based on the load of each month, which is assumed invariant throughout the month. $OVERWORK_{i,K}$ is the overwork of job *i* determined over the previous and the reference month (K=2). Then the $\overline{AVERAGE\_LOAD}$ of Eq. (5.2) is the average load in the unit over the entire reference period of Table 5.2 (March-September) and *N(K,i)* is the number of jobs completed in the previous and reference month. For example, overwork for April is:

$$OVERWORK_{Apr,1} = \frac{1}{(3078+3187)} \times [3078 \times (1.00-0.77) + 3187 \times (0.95-0.77)] = 0.203 \quad \textbf{(5.3)}$$

Considering the example above, overwork in April is high (0.203), since load in March and April was considerably above the average load of the entire period (29% and 23% respectively).

To investigate the effect of load and overwork on the system's processing time and quality, and in the absence of detailed recorded data, we conducted individual 45 min structured interviews with 26 out of 40 operators of the system under study. The operators were asked (see Appendix D.2) to estimate how much above the norm their processing speed and the probability of making an error (quality) would increase as the load and overwork increase. Since this was a judgmental estimation, we asked the operators to present relevant examples, which we used to validate their responses. Whenever significant deviations were detected among responses, a second round of interviews was conducted to drill down and understand the causes of these deviations. From the interviews with the operators, it became apparent that operator performance degrades under conditions of high load and overwork. This degradation would be more pronounced for low-skilled or less experienced operators; however, to simplify the study we assumed that all operators are of equal skill. The results of the survey are presented in Table 5.3. Table 5.3, presents the average percentage change of processing time and quality for various levels of load and overwork. These averages are determined considering all responses from the 26 operators; for example, when load is 11%-20% above the norm and overwork is 0, the operators on average will increase their processing speed by 8%, while the probability of making an error (quality) will increase by 3%.

Table 5.3: Percentage change of processing time and quality for various levels of load and overwork

		a) Processing Time				b) Quality			
		Overwork increase, #							
		≤0.00	0.01-0.10	0.11-0.20	> 0.20	≤ 0.00	0.01-0.10	0.11-0.20	> 0.20
Load increase, %	0	0	9	17	26	0	6	11	18
	1-10	-4	5	12	21	1	7	12	19
	11-20	-8	0	8	16	3	9	14	22
	21-30	-13	-5	2	10	7	13	19	26
	31-40	-18	-11	-4	3	10	17	22	30
	41-50	-21	-14	-8	0	13	20	25	33
	50>	-25	-18	-12	-6	17	24	30	38

Source: Interviews with N=26 operators, average values

From the table above, speed increases with load and decreases with overwork, while quality degrades with both load and overwork. Considering the month of April, and the related values of load and overwork in Table 5.2 (23% and 0.203), we derive from the table above that in April the processing time will increase by 10% and the quality will deteriorate by 26%.

In the simulation model, we used the data of Table 5.2 to define the load and overwork inputs at the time each job enters the system, and the data of Table 5.3 to calculate the changes in the mean values of the processing time and quality rate outputs for that job. This was done for all jobs during the execution of the simulation model. In the following Section, we detail the approach used to model the effect of all five experimental factors in the simulation model.

5.4.4 Simulation modeling and experiments

We used the Arena simulation software to develop two simulation models, representing the functional and cellular structures as presented in Figure 5.1 and Figure 5.2, respectively. The two main process flows (i.e. corporate actions and customer queries) of the functional (baseline) structure were modeled using existing flow charts and job manuals. System demand (mean values), absenteeism and overtime data were based on actual values from the previous year. Processing time and quality rate data were based on the typical mean values used for planning; however, the transformation team spent more than 40 hours of direct observations (time studies and quality assessments) to validate these values during a three week diagnostic period. For those cases for which data were not available (either not tracked or the jobs were not executed during this diagnostic period), we organized workshops with responsible staff and team leaders for estimating missing model parameters. The cellular structure was developed during the design phase of the transformation project mentioned above. The same parameter values were used as those of the functional structure, while the differences in roles and process flows were discussed with the management team and obtained their agreement. Table D.3 in Appendix D, summarizes the key parameters and assumptions in the two models, their values and sources.

Table D.4 in Appendix D, presents the processing times, quality rates and experimental factors for each job in the system. For example, the job Processing Information (row 2) is always executed (100% probability of occurrence) and the related processing time follows the lognormal distribution with mean and standard deviation 13.5 (minutes). In the simulation model, the values of the mean and standard deviation of this processing time will change according to the levels of the three factors STDE, STRA, and STRE. Consider the STDE factor and the month of April in the example of the previous Section. At the SI (state independent) level the mean and standard deviation will remain invariant, while at the SD (state dependent) level they will both increase to 14.8 (13.5 + 13.5×10%). Similarly, for the factors STRA and STRE, the setup associated with the job Processing Information (2.7 min) will change according to the levels of these factors (0.00, 0.30 and 0.60).

To ensure proper representation of reality, we calibrated the simulation by a) comparing the model's throughput results of the functional arrangement with the actual throughput values (Table 5.4), and b) validating the results including all inputs and assumptions with management. Table 5.4 and management's feedback indicated that the model represented adequately the dynamics of the system.

Table 5.4: Actual vs. simulated throughput (events completed) performance for the information-processing unit

Month	Actual	Simulated	Delta (%)
Apr	2,626	2,599	-1.0
May	2,733	2,725	-0.3
Jun	1,736	1,778	2.4

Regarding the simulation experiments, for each combination of the factor values, we ran two sets of simulations, one for each structure. Fifty repetitions were conducted for each set. Noting that the IIRE factor is applicable only to the cellular structure, the numbers of simulation runs for the cellular and functional structures are $2^2 x 3^3 x 50=5400$ and $2^2 x 3^2 x 50=1800$, respectively.

To assess the statistical significance of the selected factors and their interactions, we examined their P-values with the level of significance set to α=0.05. We also validated the assumption of normality for the residuals, which underpins the experimental procedure. The statistical analysis was performed using the Minitab statistical software. Finally, it is noted that the simulated period was 62 business days (three months) long, out of which the first 20 days were devoted to system warm-up, and the related results were not used in the analysis.

5.5 Results and discussion

The analysis of the results of the full factorial experiment is presented in Table 5.5. In particular, the Table presents the statistical significance of the selected factors and their interactions on the performance differences of the four metrics between the cellular and functional structures. In reviewing the results, all main factors (marked with * in Table 5.5) appear to be significant at the 0.05 α-level for all performance measures. There are also certain two-way interactions (also marked with *) that are significant at the 0.05 level across all performance measures.

Table 5.5: Factors and statistical significance at α=0.05 (p-value)

	PICT		PIWIP		PIQT		PIUT	
Source	F-value	p-value	F-value	p-value	F-value	p-value	F-value	p-value
A: STDE*	8405.8	0.00	9113.7	0.00	2479.5	0.00	4355.9	0.00
B: FLEX*	28.3	0.00	981.9	0.00	1657.4	0.00	42.9	0.00
C: STRE*	7.6	0.00	285.1	0.00	253.4	0.00	1343.2	0.00
D: IIRE*	961.7	0.00	567.1	0.00	311.3	0.00	2904.5	0.00
E: STRA*	579.2	0.00	1718.5	0.00	1676.3	0.00	5184.4	0.00
A×B	0.3	0.61	1.4	0.24	0.2	0.68	71.9	0.00
A×C	5.6	0.00	2.3	0.10	7.4	0.00	6.6	0.00
A×D	8.6	0.00	0.3	0.73	3.4	0.04	1.7	0.18
A×E	4.1	0.02	2.1	0.12	42.6	0.00	15.6	0.00
B×C	5.9	0.00	18.5	0.00	8.5	0.00	2.8	0.06
B×D	0.4	0.70	16.3	0.00	18.4	0.00	1.1	0.33
B×E*	16.0	0.00	82.5	0.00	22.3	0.00	87.9	0.00
C×D	0.8	0.54	1.1	0.36	3.5	0.01	1.2	0.30
C×E*	41.6	0.00	153.3	0.00	118.5	0.00	278.6	0.00

	PICT		PIWIP		PIQT		PIUT	
Source	F-value	p-value	F-value	p-value	F-value	p-value	F-value	p-value
D×E	1.4	0.24	0.5	0.74	2.7	0.03	0.6	0.65
A×B×C	4.1	0.02	14.1	0.00	8.6	0.00	0.6	0.53
A×B×D	1.4	0.26	2.9	0.05	5.5	0.00	1.5	0.24
A×C×D	0.2	0.94	0.3	0.91	0.6	0.70	0.6	0.70
A×B×E	0.2	0.81	1.2	0.29	8.7	0.00	1.0	0.38
A×C×E	0.1	0.97	0.1	0.98	2.5	0.04	0.7	0.62
A×D×E	0.0	1.00	0.0	1.00	0.1	0.97	0.3	0.85
B×C×D	0.9	0.44	0.7	0.58	0.6	0.67	2.5	0.04
B×C×E	2.0	0.09	2.0	0.09	2.5	0.04	1.1	0.36
B×D×E	0.2	0.93	0.4	0.78	0.5	0.76	0.2	0.93
C×D×E	0.8	0.59	0.3	0.98	0.3	0.97	1.0	0.42
A×B×C×D	0.8	0.53	0.4	0.83	0.2	0.96	0.6	0.65
A×B×C×E	3.0	0.02	1.1	0.38	0.5	0.73	1.6	0.17
A×B×D×E	0.5	0.76	0.2	0.95	0.1	0.97	0.3	0.88
A×C×D×E	0.2	1.00	0.2	0.99	0.3	0.98	0.0	1.00
B×C×D×E	0.2	0.99	0.1	1.00	0.1	1.00	0.2	1.00
A×B×C×D×E	0.6	0.75	0.2	0.98	0.2	0.99	0.8	0.65
		R^2 = 68.5%		R^2 = 74.8%		R^2 = 63.2%		R^2 = 82.0%

* Main factors and interactions significant at the 0.05 a-level for all performance measures

The Main Effects Plot (Figure 5.3) indicates the impact of the main factors on PICT, PIWIP, PIQT and PIUT. All the findings are in line with past literature (Swank, 2003; Pagell and Melnyk, 2004; Hameri, 2011), and suggest that the conversion to the cellular structure improves (decreases) Cycle Time and WIP (by 17% on average), as well as Utilization (by 11%). This can be seen by focusing on the average values of Figure 5.3a, b, and d, and noting that the definitions and Eq. (5.1**)** of PICT, PIWIP, and PIUT imply improvement from the conversion of the functional to the cellular structures. The results also confirm a potential negative effect of cellular structures in services reported in past research (Harvey, 1989; Pagell and Melnyk, 2004); that is, the increase of the initial waiting period. Indeed, as indicated in Figure 5.3c, Queue Time deteriorates (increases) on average by 9% due to the conversion to the cellular structure. These averages are determined considering all levels of the five factors.

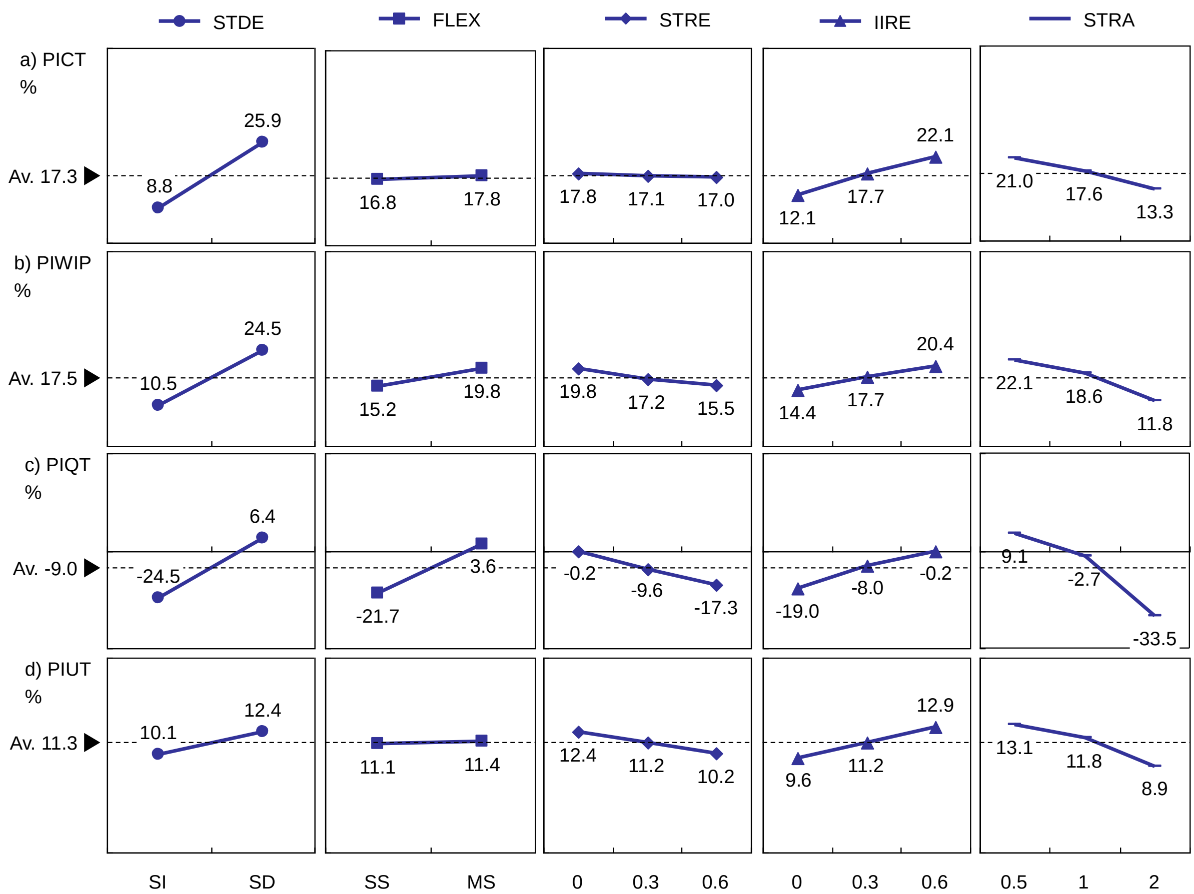


Figure 5.3: Main effects plot (data means) for (a) cycle time, (b) work in process, (c) queue time, and (d) utilization

The performance improvement of the cellular structure is attributed to a number of factors: a) the reduced need for setups (66% probability to perform setups in the functional structure versus 44% in the cellular); b) the eliminated hand-off steps (operators able to rework their own errors); c) one reduced decision layer in customer queries (due to the elimination of the investigation team leader role); and finally d) the fact that load is better balanced in the cellular structure. The latter point confirms past evidence from manufacturing regarding the role of bottlenecks in system congestion (Garza and Smunt, 1991; Johnson and Wemmerlöv, 1996; Shambu *et al.*, 1996; Agarwal and Sarkis, 1998; Assad *et al.*, 2003). Indicatively (Figure 5.4), in the functional structure average utilization and queue time are higher in the information-processing unit, than in Cells A, B and C. This is attributed to the fact that in the cellular structure more operators are available to execute the Information Processing job, hence workload is better balanced.

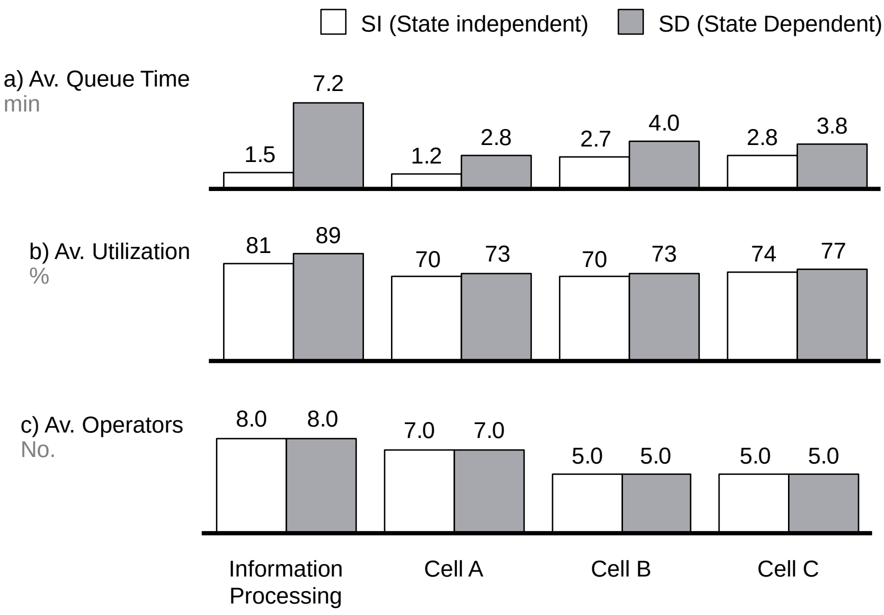


Figure 5.4: Average queue time, utilization and available operators for the information processing unit and cells a, b and c

STDE (State dependency) has the strongest effect on PICT and PIWIP (Figure 5.3a, b). We also observe that the difference between the two structures is becoming considerably higher in the SD scenario. SD captures the fatigue and hurried behavior of operators under increasing load, which slows down processing time and increases rework. This *dysfunctional behavior* congests those units that include bottlenecks even further, and, consequently, the entire performance of the functional structure deteriorates. Such congestion is not apparent in the SI scenario, in which processing time and quality are assumed to be independent of the load and overwork in the system. The implication here is that, in server dependent systems, the adoption of cells needs to avoid the emergence of bottlenecks, since a potential congestion will deteriorate the system even further.

FLEX (Operators' Flexibility) has a strong effect on PIQT (Figure 5.3c); however, the effect of FLEX on the rest of the performance measures is not as high as it has been observed in manufacturing (Ruiz-Torres and Mahmoodi, 2007). MS (multi-skilled focused) in particular, reduces the initial waiting time in the cellular structure, while SS (single-skilled focused) produces better results in the functional structure. This implies that more benefits can be achieved if the right level of expertise is applied in each structure, i.e. cross-skilling is better suited in the cellular structure while single-skilling (experts) is preferable in the functional one.

IIRE (Interaction Intensity Reduction) has a strong effect on all performance measures (Figure 5.3). Obviously, the higher the reduction in inter-unit interactions, the higher is the performance improvement from the conversion to the cellular structure. In line with past work

(Swank, 2003), cells can reduce loop-backs and work returning to previous steps for further processing. Hence the reduction of interactions may also be a significant lever for improvement, in addition to setup reduction. Intuitively we would expect that for environments with high information dependencies, and hence probability for more errors during hand-offs, the cellular structure is better performing.

STRE (Setup Reduction) has a strong effect on PIQT and PIUT (Figure 5.3c, d). In addition, the performance improvement of the cellular structure decreases as the level of STRE increases, implying that the functional structure may benefit from substantial setup reduction through prioritization. In the cellular structure the reduction is not as significant, since setup has been already reduced by the adoption of cells.

STRA (Setup Ratio) has the strongest effect on PIQT and PIUT (Figure 5.3c, d), while the performance improvement of the cellular structure decreases as the level of STRA increases. The performance of the cellular structure deteriorates as the job-setup increases compared to the market-setup, an effect which cannot be offset even for the higher values of FLEX and STRE (see interaction plots in Figure 5.5).

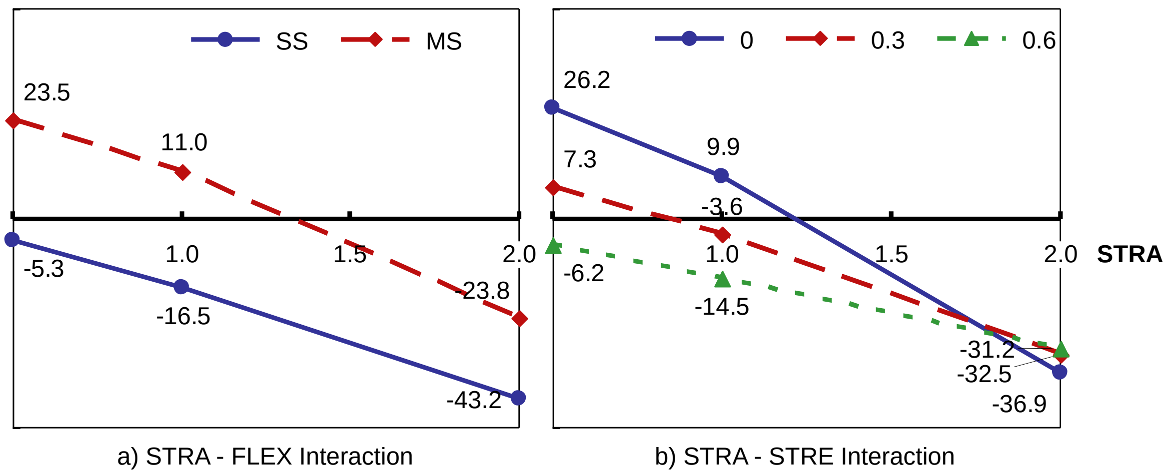


Figure 5.5: Interaction plots for percentage improvement in queue time: a) STRA-FLEX interaction, b) STRA-STRE interaction

Chapter 6. Conclusions and discussion

6.1 Synthesis: main findings and managerial implications

In this dissertation we investigated whether and in what extent LM concepts can be adopted and adapted in service environments. To do so, *first* we examined the differences between manufacturing and services and the underlying challenges. We compared, in a systematic way, various service archetypes to manufacturing considering significant service characteristics and managerial challenges. *Subsequently*, we performed an exhaustive review of LM by examining its historical evolution and key components, its impact and limitations, and finally the aspects that have made this approach revolutionary. *Finally*, we critically reviewed three distinctive streams of lean in services. In particular, we reviewed a) how relevant, from the conceptual standpoint, are the LM concepts in services (i.e. *applicability*), b) the lean practices and implementation approaches used in various service sectors and functions (*transferability*), and c) the conditions to maintain continuous improvement in service organizations (*sustainability*).

Utilizing the above analysis, we identified ten gaps that we consider critical for exploiting lean in services and focused on four of them (1st, 2nd, 4th and 9th). In particular, we clarified the essence and limitations of lean in services, we provided a universal framework for classifying services, and examined the applicability of two of the most well-known lean concepts (quality at source and cellular work structure) in a service environment of high complexity . We discuss in the next paragraphs the main findings and the managerial implications from our investigation.

In the area of lean services (1st Gap) we have leveraged the original work of Hopp and Spearman (2004), de Treville and Antonakis (2006) and Hopp (2013) and provided a new definition for lean. That is, "the objective of LM is *long term profitability* according to the company's strategy; this is achieved through *minimization of waste and undesirable variability*, *minimal buffering costs* (or maintained at the level that *maximize profits and cash flow)* and a *self-motivated workforce* to drive continuous improvement". This definition encompasses some important characteristics.

First, it maintains the key concepts of minimizing waste and achieving long-term profitability with minimal buffering costs (capacity, time and inventory or quality for some type of services). However, the drivers to minimize waste and the buffering costs might not be the same for all types of services. For example consider the capacity buffer that in addition to human resources of an organization, might entail outsource providers (since part or the entire service may be outsourced to outside vendors), customers (since customers execute part or the entire service through self-service options) and technology (since, for example, Artificial Intelligence is gradually replacing human labor in several areas). Quality may also be used as a buffer, since in some service environments it can be adjusted so that personnel may cope with demand fluctuations. Therefore, understanding the drivers of waste minimization and finding the right mix of buffering costs are critical levers for achieving lean services.

Second, it introduces the concept of undesirable variability, in the sense that not all types of variability are subject to elimination, but only the ones that do not support the organization's strategy. For example, high customization and customer participation should be pursued from service firms following a differentiation strategy. Therefore, defining what constitutes undesirable variability and finding practices to eliminate it or embed desired customization in services (e.g. through modularization and resource flexibility), are also critical levers for achieving lean services.

Third, it includes the self-motivated workforce component which is a critical driver of continuous improvement. As already discussed, managing improvement programs as a pure cost reduction exercise (e.g. through layoffs) might place the sustainability of an organization at risk. While job security benefits an organization in the long-run (as higher commitment leads to higher quality and productivity), maintaining resources (as opposed to letting them go as a result of early successes of the program) worsens financial performance (Keating *et al.*, 1999). Senior managers, therefore, need to balance short versus long-term objectives taking into account performance improvement patterns and market conditions (Sterman *et al.*, 1997).

Although this definition is relevant to both manufacturing and services, from the above we conclude that each component needs to be adjusted depending on the organization's strategy and on the characteristics of each service (namely on *customer participation*, *labor intensity*, *stockability*, and *simultaneity of production and consumption).*

<u>In the area of service science (2^{nd} Gap)</u>, we have leveraged existing, important work on service classification systems and identified the most significant attributes to be considered in service management. We proposed the Service Attribute-Process Matrix (SAPM), which compares and synthesizes the service classification attributes to a comprehensive framework. Thus, SAPM is a tool designed to help service system designers and management professionals investigate the importance of the identified service attributes to major processes of the service life cycle. Specifically, SAPM:

a. Integrates the important findings in the service classification literature under a systematic framework. This is done by associating the influence of key service attributes to the major processes of the service life cycle. Thus, SAPM highlights the main attributes involved in each process helping the service designer engineer the service delivery system in a way that balances the effects of each attribute across the entire spectrum of life cycle processes, thus promoting an integrated system development
b. Reveals the interrelations between different service classification attributes, providing insights to the service system designer regarding how a decision for a certain attribute will influence related attributes

c. Reveals processes that involve major complexities, i.e. those processes influenced strongly by a multitude of factors, thus helping the designer to manage process complexity by trading-off among service attributes.

One major conclusion of this part of the work is that no service classification scheme is universal and applicable to all processes of the service life cycle. The implication from a lean perspective is that lean cannot be implemented in the same way in every service environment. One has to deal separately with each business process in order to identify the service attributes that mostly influence each process. Overall, the most influential attributes relate a) to the *customer,* including the type of *customer* (i.e. individual vs. organizations), the *contact model* (i.e. the extent of customer interaction), and the *customer influence* (i.e. the extent that the customer can influence the service offering and delivery); b) the extent that the service package is *customized*; c) the *delivery channel* used to deliver product and services. The most complex processes identified from our classification work, include the *design and development* of new services, the *marketing and selling* process and finally the *delivery of products and services*.

In the area of service quality (9^{th} Gap), we have summarized the qualitative effects of failures in service operations in Figure 6.1. This Figure is inspired by the cycle of failures in services as presented by Schlesinger (1991a); however, it has been redrawn from the operational point of view. Service failures, when detected during the service encounter, lead to rework which increases resource utilization and cycle times, leading to delays in customer service.

Furthermore, undetected mistakes normally will be identified at some point in time by customers after they have left the service system. As a consequence, delays or failures to complete customer requests (jobs) during the first contact, lead to repeated attempts from un-served or dissatisfied customers to contact the service system, which eventually increases the normal stream of arrivals of first-time visits. This fact, in turn, increases the load of the service system creating new bottlenecks, increasing queues, and causing further delays.

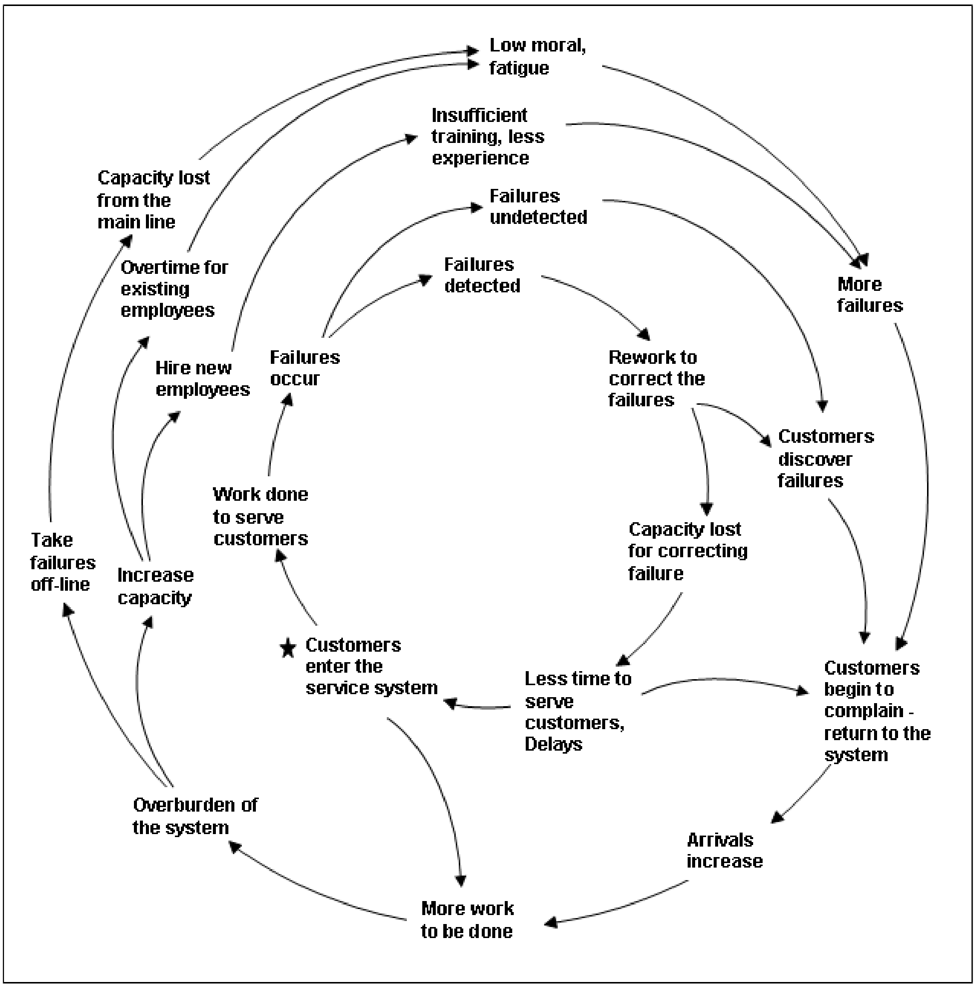


Figure 6.1: The vicious cycle of failures in service operations

When the system becomes overburdened (e.g. long backlogs, increased customer complaints), management typically acts. Usual practices include increasing capacity, chasing demand or treating failures off-line by introducing dedicated servers. In the first case, if capacity increases significantly, cycle time will decrease, thus customer service will improve, and the system will return to a satisfactory state. However, if failures increase along with capacity (due to the use of inexperienced staff), then the benefits may disappear. In the second case, if employees are pressed to increase productivity or if overtime is maintained over the long run, then further failures may be generated.

Taking failures off-line, that is using dedicated resources to deal exclusively with rework (e.g. complaint or investigation departments), may reduce the capacity of the main line, may increase cycle time and thus delays, pressure and eventually failures. Additionally, and perhaps more importantly, this practice makes failures someone else’s responsibility, reducing awareness of the causes and effects of problems (Hopp and Spearman, 2001).

The results of this part of our work suggest that failures and rework degrade the performance of service systems; metaphorically speaking, the larger the cycle of failures the further the performance of the system deteriorates. The impact is reinforced, i.e. the cycle is getting larger, if specific inputs of the system deteriorate; these include the ability of the service organization to deliver appropriate quality, speed or flexibility, to detect failures early (detection rate) and to be capable enough to recover timely and efficiently from failures (rework method). In addition, once in the cycle, it is not always obvious for service managers how to escape or reduce it. For instance, our results show that the various management practices have strengths and weaknesses depending on the characteristics of failures. If this is not taken into consideration, the above managerial practices may lead only to short-term improvements, while the main causes of failures will remain unsolved and the vicious cycle will be repeated.

Our understanding is that the best strategy for managing failures is to avoid getting into the vicious cycle in the first place. To do so, as already mentioned, the appropriate mechanisms need to be set up. Such mechanisms include failsafe techniques, walk-through audits, service guarantees, statistical process control and service recovery approaches (Fitzsimmons and Fitzsimmons, 2005). A prime candidate where these mechanisms are likely to have the greatest impact is the customer – server interface, where the largest uncertainty exists. However, back office operations as well their interfaces with the front line should not be neglected, since the outcome of their actions could affect customers on a massive scale.

Additionally, and even more importantly, the design of the service system should be continuously reviewed. Failures can be a great learning opportunity for identifying design weaknesses, especially those weaknesses that lead consistently to failure patterns. Such patterns propagate into the service system (e.g. queues will create more queues) and are usually the result of the inflexibility of the service system to cope with the variability inherent in services. Thus, the structure, processes and workforce flexibility should be continuously reviewed and challenged. Finally, new service development efforts should integrate the concept of "*serviceability*". It has been observed that several aspects of the inflexibility of service systems are due to insufficient involvement of customers and/or operators into the early stages of the design process. In summary, service organizations should aim for early detection and prevention of failures, as well as a thorough understanding of the root causes of failures and ways to address them in the long-term. The above findings validate that the *dynamic capabilities* required to achieve continuous improvement in manufacturing are relevant for services as well (discussed in Section 2.5.3: *meta-learning, sensing signals of weak performance and resilience to quality disruptions*).

In the area of cellular structures (4th Gap), past research has suggested that prior to adopting cellular operations, service providers need to cope with two categories of challenges: a) challenges common to those encountered in cellular manufacturing, and b) additional challenges stemming from the unique characteristics of services. The former category includes efficiencies required to offset the loss of pooling synergy, the ability to respond to market-mix changes, and the ability to properly manage transition challenges, especially the resistance of professionals whose autonomy might be curtailed with the adoption of cells. The latter category includes the risks associated with potential increases in initial queuing experienced by customers during service delivery. Noting that the above challenges have been investigated by service researchers at different depth and context, the current work has contributed to the field of cellular operations in services by investigating the impact of servers on system performance. Specifically, in this area we have introduced three new perspectives i.e. operator's response to changes in system's workload and overwork, operators' flexibility, and operators' interactions. We have also investigated efficiencies required to offset pulling synergies in services (a topic not investigated thoroughly in the past).

In the remaining paragraphs, we have linked the findings of this part of our work to significant past literature in order to highlight our contributions. Furthermore, since each of the above challenges entails important design considerations, we highlight the associated managerial implications that service managers and consultants need to focus upon before transforming a functional structure to a cellular one. These design considerations include:

Efficiencies to offset the loss of pooling synergy. As already mentioned, the efficiencies required for cellular operations to bring substantial benefits are well known and have been studied extensively in manufacturing and anecdotally in services. The results of our work confirm past service literature (Swank, 2003; Pagell and Melnyk, 2004; Hameri, 2011) and suggest that the conversion to the cellular structure improves operational system performance and in particular, cycle time, work in process, and utilization. This is achieved, through the reduction in the frequency and duration of setups, the elimination of duplicate tasks and the reduction of administrative and management layers. A rather obvious implication is that service managers need to investigate thoroughly whether relevant issues impose limitations in the functional structure, and may be addressed effectively via the conversion. However, while duplicate tasks and unnecessary layers can be easily identified, setup reductions might be more challenging to detect prior to the conversion. Therefore, it is becoming critical for service managers to pilot any changes prior to scaling them into the organization, using the advantage they have over their manufacturing counterparts in reconfiguring much faster and with less costs the layout. Most importantly, service managers need also to exhaust all potential improvements in the existing functional structure prior to embarking to the transformation to a cellular one. Our analysis indicated that prioritization rules that minimize the need for setup can have more substantial benefits in the functional than in the cellular structure.

Operators' response to systems changes. The adverse effects of workload pressure and overwork on service providers have been studied in the past (Oliva and Stearman, 2001; Kc and Terwiesch, 2009), however, not from the cellular operations standpoint. Our results indicate that processing time and service quality erode when operators are under workload pressure. Their behavior is becoming more dysfunctional especially in systems with significant bottlenecks. In line with past evidence in manufacturing (Garza and Smunt, 1991; Johnson and Wemmerlöv, 1996; Shambu *et al.*, 1996; Agarwal and Sarkis, 1998; Assad *et al.*, 2003), our results imply that the adoption of cells should prevent the emergence of bottlenecks and their adverse impact on the behavior of operators. In contrast to past studies though, our results indicate that operators' dysfunctional behavior requires particular consideration in service systems since it can congest a system faster and at a greater extent. Such congestion is not apparent in a manufacturing setting, where processing time and quality are assumed to be independent of the load in the system. Therefore, service managers need to establish mechanisms that provide visibility and allow a preventive, rapid rebalancing of the workload (e.g. setting thresholds in queues that, once exceeded, trigger the execution of already established reconfigurations of the available resources, developing algorithms for automating assignment of work). Managers need to be also aware that additional investment might be required to develop those mechanisms (e.g. acquire new resources or equipment, invest in cross-skilling, etc.).

Operators' Flexibility. Consistent with previous research (Harvey, 1989; Pagell and Melnyk, 2004), the results of our work confirm that, while cycle time improves from the adoption of cells, initial waiting deteriorates. The results also illustrate that the increase in initial waiting may be reduced by using cross-skilled operators. This points out workforce flexibility as a key driver to mitigate potential negative effects from the adoption of cells, such as the increased initial (queue) waiting and the inflexibility to respond to market-mix changes. Service managers need to investigate potential limitations in developing the skills to perform an array of tasks. It might be the case that several regulatory (e.g. limited access to customer information from outsourcing partners due to confidentiality), technical (e.g. independent platforms 'not speaking' to each other), or budget and time constrains (e.g. certain skills require considerable amount of time and effort to be acquired and maintained) prevent the establishment of cells and cross-training. Managers need also to be aware and apply techniques that can help them acquire the benefits of cross-training with the lowest possible effort (Hopp and Van Oyen, 2004).

Operators' Interactions. Through our field observations, we have noticed that decoupling jobs with heavy information requirements results in increased interactions and duplication of work. Standardizing the content of information may only partially address the information exchange problem, as professionals will be inclined to dysfunctional behavior and adjust their output quality when the workload pressure is high. Our results, in line with past research (Swank, 2003), also show that by integrating narrow, specialized functions, into broader cross-disciplinary units can bring tangible benefits. These include the reduction of overlaps and hand-offs due to rework, as a result of the ability of professionals to perform more tasks and have access to more information.

Advocates of overall integration suggest additional, intangible, benefits by working into cells, such as continuous improvement and innovation, as a result of having professionals from different disciplines work, challenge and learn from each other (Frei, 2008). Noting that some professionals might resist the prospect of losing their functional autonomy by working into cells (Young *et al.*, 2004), the issue of selecting the appropriate degree of integration is becoming critical in service design. For example, in the environment we have investigated (service shop towards professional services), the cellular structure seems appropriate but under certain conditions. In more pure professional environments the reduction of professional autonomy may have more severe effects on creativity and quality. Service managers might have to select the appropriate degree of integration while respecting individual preferences. Past research (De Treville and Antonakis, 2006; Hopp, 2013), suggests that service managers can do so, by reconsidering thoroughly certain aspects of professional work, such as meaningfulness, responsibility and feedback, given the context of their industry and specific business model.

Overall, our findings indicate that two of the most well-known lean concepts (quality at source and cellular work structure) are relevant in a highly complex service environment as they are in manufacturing, under certain conditions. The results from the two simulation models suggest that by addressing quality issues at source and by using a cellular arrangement in a service setting may have significant positive effects on system performance, if some conditions apply. The results also indicate that service managers, in addition to challenges encountered in manufacturing (e.g. trade-offs between different layouts), they have to address unique challenges driven primarily by customers participating in service production and the propensity of knowledge-intensive employees to prefer professional autonomy. From the universal transferability standpoint, we conclude that while it is advisable for service organizations to adopt the essential principles and elements of lean, they will have to ultimately adapt and evolve these principles into practices and new models better suited to their unique environment and challenges. To do so, and continuously improve, it is essential for service organizations to develop *dynamic capabilities* of identifying the real causes of problems, sensing signals of weak performance and responding rapidly to changes in the environment.

The above findings, although derived from experiments in financial services, are relevant to other *information and people-intensive* service environments (i.e. where the main objects of transformation are information, customers and employees), such as the supporting functions of any organization (e.g. human resource management, finance, IT), or services across sectors (e.g. emergency departments in healthcare, call centers, back-office operations in banking, claims and underwriting in insurance). The current research organizes the existing knowledge around lean in services and hopefully will inspire further research on topics left outside the scope of this dissertation. We discuss the opportunities for further research in the following Section.

6.2 Recommendations for future research

In the next paragraphs, we summarize immediate opportunities for future research in the application of LM concepts in service environments.

<u>In the area of service science</u>: Future research around service classification includes the empirical validation of the SAPM framework in a representative sample of service systems and organizations and in particular in the area of e-services. It may also be worth investigating how SAPM can be enhanced to support management of certain service aspects, one of which is the variability introduced by the customer. Finally, as mentioned earlier, SAPM provides a *generic modular architecture* for services that can be used as a basis to explore the concept of *modularity in services*, a field that is attracting increasing interest in the wider modularity literature.

In the area of lean services: we identified the gaps in the lean service literature in earlier parts of this dissertation (Section 2.6.1). These gaps, and in particular the ones not addressed in the current dissertation, represent immediate research opportunities. We consider as priorities: the extension of lean-related research in *professional services and service supply chains*, the *role of new technologies and AI* in the context of lean services, the *role of lean as an innovation driver* to reshape the service environment and the importance of *controlling work in progress* in services. Another important research opportunity is the *integration of lean services and lean manufacturing* in the context of servitization. Given the increasing importance of servitization, achieving efficiencies in both production and service is an important lever to achieve lean in a manufacturing organization.

In the area of service quality: Future research includes empirical validation of the best strategies for the prevention of failures in the design of product/services from the *"serviceability"* standpoint. Several root causes of failures in services can be attributed to the design process (e.g. complex product customizations that do not justify the associated costs for managing the related complexity, failure to adequately involve customers and operators into the early stages of the design process, etc.). Subsequently, an interesting point for further investigation is the policies and practices that increase an organization's capability to *sense signals of weak performance*. This includes the types of mechanisms and practices that should be put in place, the stages in the service life cycle that these mechanisms/practices should be integrated (i.e. customer–server vs front–back office interface), as well as predefined countermeasures to respond to failures.

In the area of cellular structures: Future research opportunities include the analysis of empirical studies related to the effects of workload and fatigue on operators' and system's performance. In our case study we used a rather limited sample of professionals. A second interesting research topic concerns clustering resources into cells in a service setting; it is noted that the challenge here stems from the fact that existing services, processes and organizational structures create complex dependencies that eventually drive system behavior. Related questions to drive research in this area include: what should be the principle factors to consider in determining the cellular structure (customer, product, process or geography?), or what is the minimum size of resources that would make the formation of cells beneficial and meaningful? Finally, an interesting research topic concerns the development of algorithms for automating assignment of work that will help service managers to rapidly rebalance workload. This can be investigated both in the context of an organization's resources but also across entities through electronic marketplaces (such as Amazon’s Home & Business Services) for bridging buyers and service providers.

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Appendices

Appendix A: Lean manufacturing practices, tools and techniques

Table A.1: Lean manufacturing practices, tools and techniques

Dimension	Practice	Tools and Techniques	Source(s)*
1. Strategy and Policy Deployment	1.1 Setting manufacturing strategy in line with business strategy	1.1.1 Setting (agile) manufacturing strategies, to support the business strategy, including: - Strategic management of buffers (inventory, capacity and time) - Focused factory production strategy. A single plant is divided into several focused, self-contained factory units, grouped around process flows each with a specific product line or customer focus (mini-businesses), and control over supporting activities (e.g. maintenance, purchasing, scheduling)	(3), (5), (6), (10), (14)
	1.2 Policy Deployment, cascading and	1.2.1 Policy Deployment (a.k.a. Hoshin Kanri). A method for ensuring that the strategic goals of a company are cascaded and drive progress and action at every level within that company	(1), (9)

Dimension	Practice	Tools and Techniques	Source(s)*
	monitoring strategic goals	1.2.2 Activity-based costing (ABC). Accounting method that directly associates the cost of each overhead activity with the product being made. This reveals the true costs of the batch system and can trigger cell formations, DFMA and supplier reduction	(12)
2. Customer Focus	2.1 Voice of the Customer (VOC), understanding customers and their needs	2.1.1 The company actively and regularly seek customer feedback about: - its performance on quality, delivery and customer satisfaction (e.g. feedback after transaction, surveys) - current and future demand information, to predict demand accurately and adapt production	(2), (11), (17)
		2.1.2 Customer needs and expectations are effectively disseminated and understood throughout the workforce	(17)
		2.1.3 Customer needs are prioritized and combined with product/ service design criteria, taking into account competitive considerations with the use of the Quality Function Deployment (QFD) matrix	(12)
	2.2 Customer involvement, developing innovative relationships with customers	2.2.1 The company is in close contact with its customers and able to transmit faster and more intense information on their needs, through: - easy to access communication channels - systems that link customers directly to the factory's order entry and production control system, - customers often visiting the company's plants	(1), (11), (15), (17)
		2.2.2 Customers are actively involved in current and future Product Offerings and Product Design, intervening in the design, manufacturing, delivery and consumption of products and services	(2), (11), (15),
		2.2.3 Demand Management, i.e. managing demand with (non) monetary initiatives e.g. commercial actions to stabilize demand	(2)
	2.3 Meeting Customer Needs, delivering reliably according to customer expectations	2.3.1 Capability and Competence of Sales Network	(2)
		2.3.2 Reliable and Prompt Deliveries. Customers receive just-in-time, reliable deliveries, including an effective process for resolving customers' complaints	(2), (13), (17)
		2.3.3 Flexibility on Meeting Customer Requirements (volume and mix changes) in a personalized, flexible, and complete manner	(2), (13)
		2.3.4 Service-Enhanced Product. Offering an integrated supply of "bundles" including a combination of products and services to meet the needs of individual customers	(2)
3. Process and Equipment Management	3.1 Continuous Flow Production (a.k.a. Flow Lines) by eliminating the system constrains requiring large batches sizes from "silos" (shops)	3.1.1 Cellular Manufacturing (a.k.a. Group Technology). Methodology for organizing the factory layout in products (parts), grouped in families based on similar processing and/ or routing requirements. Machines and equipment are grouped according to these families, creating manufacturing cells (U-shaped) that process similar parts and reduce setup times and space	(2)-(5), (7), (11), (13)-(17)
		3.1.2 Setup Time Reduction. Reducing setup times and costs related to changing production from one product to another, through: - Single Minute Exchange of Dies (SMED) methodology for converting internal to external setup activities and performing them in parallel - Other quick changeover techniques e.g. one-motion methods, electronic data storage and transfer, etc. - Products and processes simplification and standardization	(2)-(5), (7), (11), (13)-(17)

Dimension	Practice	Tools and Techniques	Source(s)*
		Usage of multi-purpose machinery equipment	
		3.1.3 Small Lot Sizing. Reducing process batch (lot) sizes, to the ideal state of one ("one-piece-flow") for achieving continuous flow	(2), (4)-(6), (13)-(16)
	3.2 Total Productive Maintenance (TPM). Reducing equipment downtime by optimizing predictive, preventive and corrective maintenance activities	3.2.1 Preventive and Predictive Maintenance. All equipment is maintained regularly to minimize the frequency and duration of machine break-downs, through rigorous, regularly scheduled, pre-emptive replacement of components or predictive (preventive) maintenance programs	(2)-(5), (7), (8), (11), (14), (15)
		3.2.2 Autonomous Maintenance. A portion of everyday activities is dedicated to planned equipment maintenance programs and daily routines owned by shop-floor employees, such as the initial control before starting production, daily machine checking, etc.	(5), (7), (8), (11), (16)
		3.2.3 Excellent records are kept and posted on the shop-floor for active sharing with employees, such as past activities of equipment maintenance and post equipment records e.g. Overall Equipment Effectiveness (OEE)	(5), (7), (11), (16)
	3.3. Health, Safety and Workspace Organization	3.3.1 5S methodology for organizing, implementing and sustaining a productive work environment, e.g. point of use systems for positioning required resources at the site of production	(13), (14), (16)
		3.3.2 Safety and Hygiene Environment improvement programs	(5), (7), (11), (14), (16)
	3.4 Autonomation (a.k.a. Jidoka) and use of Machines, Equipment and Technologies	3.4.1 Progressive Use of New Process Technologies	(2), (5), (7), (11), (14)
		3.4.2 Increasing the level of automation	(7), (14)
		3.4.3 Error-Proof (Foolproof) Equipment (a.k.a. Poka-Yoke). Foolproof techniques seek to eliminate judgement and discretion in performing production tasks to produce high-reliability products	(2), (4), (5), (14), (16), (17)
		3.4.4 Acquiring machinery for reducing setup or preparation time, e.g. use of multi-purpose (function) machinery equipment	(4), (7), (14)
		3.4.5 Vertical information systems and communication from Management, providing information regularly and directly on the shop-floor: - Internal performance both strategic (e.g. long-term market and production plans, financial performance) and operational (e.g. quality, time, productivity), - External performance comparison via Competitive benchmarking	(1), (5), (6), (13)
4. Quality (product and process)	4.1 Total Quality Management (TQM) (a.k.a. Total Quality Control, TQC).	4.1.1 Quality is the top priority of the production system by all functions and levels in the organization	(2), (10), (12), (6), (5), (11), (14)
	4.2 A philosophy and integrated system for improving process and product quality	4.2.1 Involvement in sustaining and improving Quality is required by all functions and levels in the organization	(2), (12), (6), (5), (11), (14)

Dimension	Practice	Tools and Techniques	Source(s)*
		4.2.2 Extensive use of statistical techniques to reduce process variance and maintain process capability, e.g. Statistical Process Control (SPC), Process Capability, etc. with large number of equipment and/ or processes being under SPC	(2), (4)-(6), (11)-(14), (17)
		4.2.3 Quality at Source, including: - Self-inspection, i.e. inspecting and correcting one's own errors to learn from failures and avoid them in the future, and Other techniques such as in-process control inspection, successive checking, 100% checks into the processes, N = 2 first and last piece inspection, etc.	(4), (12), (14), (17)
		4.2.4 Visual management, e.g. boards, meters, charts, andon (warning light), etc. for easy-to-see quality and immediate feedback to upstream (internal and external) operations	(12), (14), (16)
		4.2.5 Strict quality assurance and insistence on compliance to quality standards, product specifications, and standard work methods from (internal and external) operations (e.g. don't accept, don't pass bad quality)	(4), (12), (13)
		4.2.6 Stop-and-fix mode, i.e. line-stop for nonconformities with engineers located near the shop floor to provide quick assistance	(4), (12), (13)
		4.2.7 Quality Circles (QC), formal groups from cross-functional employees that meet regularly (in circles) to: - achieve Product and Process Quality Improvements (salary and terms and conditions of work, discussed in other channels) - encourage employee participation in problem solving and decision making embed continuity by keeping the circles intact from project to project	(3), (5), (6), (14)
5. Continuous Improvement	5.1 A philosophy and intergraded system of continual improvement	5.1.1 Every product and process are continuously evaluated and improved in terms of time, resources, quality and other relevant aspects, instead of taking a static view	(3), (5), (6), (13), (14), (17)
		5.1.2 Employee participation and cooperation across functions and organizations is emphasized and encouraged	(3), (5), (6), (14)
		5.1.3 Kaizen initiatives and events. Diverse teams are formed to work on various operational improvement projects e.g. - reduction of cycle time - reduction of WIP - product and process simplification Because they are one-off (discontinuous) projects they produce better results when combined with QCs	(2), (5), (6)
		5.1.4 Continuous Improvement tools and concepts, e.g. - Mura-Muri-Muda, 7 types of waste, quality at source, one-piece-flow, root-cause-problem solving - Problem Solving Quality Tools, e.g. Fishbone, Pareto Diagram, 5 Whys technique, Failure Mode and Effect Analysis and - Process Improvement Techniques, e.g. Value Stream Mapping, Process Diagrams, Simplification and Standardization, Reengineering processes, Time and Motion studies, Suggestion programs	(5)-(7), (14), (16)
		5.1.5 Work standardization and Standard Operating Procedures (SOPs). Standardizing and documenting with detailed descriptions production tasks to: - capture organizational learning (knowledge management), - help in training and ISO 9000 compliance, maintain the cumulative effect of continuous improvement	(1), (5), (14), (17)

Dimension	Practice	Tools and Techniques	Source(s)*
	5.2 Product Design methodologies and practices	5.2.1 Quality Loss Function, featuring robust design and efficient experimental design methodology, e.g. Design of Experiments (DOE), process capability studies performed before product launch, etc.	(11), (12)
		5.2.2 Design for Manufacture and Assembly (DFMA). Numbers and variety of parts are reduced through commonality and modularity (i.e. standardization and simplification of component parts designs), and common parts are repeatedly used saving time and costs to manufacture and assembly products and components	(2), (5), (14)
		5.2.3 Parts Standardization and Product Modularization. Modular design (an element of DFMA with implications in sourcing) requires fewer suppliers to deliver larger pre-assembled modules, reducing the number of parts, plant size and greatly simplifying assembly	(2), (14)
		5.2.4 Concurrent Engineering (a.k.a. Black Box Engineering). Several parallel sets of functional solutions are developed and validated with the customer before developing detailed dimensional definitions, limiting in this way later changes in specifications	(1), (2), (14)
		5.2.5 Phase Overlapping to minimize design changes and the total project time and cost, e.g. concurrent engineering techniques overlap the typical phases of a vehicle development program (i.e., target development, appearance concept release component, fabricate tooling, and build vehicle)	(1), (2)
		5.2.6 Mushroom Concept (a.k.a. Postponement). A production process that keeps processes and products standardized for as long as possible and creates a product structure that is diversified only at the final production stage	(2)
		5.2.7 Multi-functional Design Teams, including key Suppliers and Customers, working in a highly interactive design process	(1), (2)
6. Human Resource Management	6.1 Flexible and Multi-functional Workforce	6.1.1 Job rotation, including regular (e.g. rotation every 2 hours - 10 days) and ad-hoc (e.g. to balance workload, or for training purposes) rotation	(2)-(5), (7), (11), (13)-(17)
		6.1.2 Training. Shop-floor employees and managers receive training on a regular basis in Cross-functional tasks (various tasks in several different machines), Problem Solving and statistical methods and tools	(2)-(5), (7), (11), (13), (14), (16), (17)
		6.1.3 Flexible Capacity through Work Time Flexibility (Flextime), Outsourcing, etc.	(2)
	6.2 Employee Involvement in Continuous Improvement	6.2.1 Shop-floor employees drive suggestion programs and lead product and process improvement efforts	(1), (2), (14)
		6.2.2 Innovative systems to motivate and cross-train employees: - Performance Appraisal e.g. rewards and recognition, - Performance Related Pay Systems, e.g. pay-for-skills/knowledge, pay-for-performance, etc.	(2), (11), (14)
		6.2.3 Long-term Employment is supported by relevant policies	(14)
	6.3 Self-directed work teams for rapid Team Decision Making and Team Problem Solving	6.3.1 Job design and Job enlargement expand the Autonomy and Responsibility of the employees. - Responsibility and authority are consistently directed to the lowest levels of the organization. - Responsibilities are decentralized, and tasks previously performed by supervisors, indirect (e.g. procurement, maintenance) or direct functions (other shops), are	(1), (2), (13), (14)

Dimension	Practice	Tools and Techniques	Source(s)*
		assigned into the multi-functional work-cells (e.g. team leadership rotates among employees)	
		6.3.2 Few Levels of Management (Flat organization structure). Hierarchical levels and size of indirect teams are either reduced (as result of increasing the work content and number of tasks absorbed by the new work-cells) or eliminated (as result of root-cause corrections)	(1), (2), (13), (14)
		6.3.3 Cross-functional, self-directed teams are formed and work together to achieve common goals. Considering each opinion they are able to take decisions, identify and resolve problems more quickly and effectively	(2), (13), (14), (17)
7. Manufacturing Planning and control	7.1 Levelled Production (a.k.a. Uniform Workload, Production Smoothing or Load Levelling). Redistributing production volume and mix over time to minimize fluctuations of the daily workload	7.1.1 Synchronized Scheduling. Production schedule that is synchronized to the customer demand (e.g. releasing orders to the shop in small quantities or about 2 hours of production). Also implies that all the elements of a business - not just production - working in sync to achieve the strategic goals of the business	(2)
		7.1.2 Takt Time is the ratio of Time available during a production period over the Unit Demand during that period. Defines the exact pace at which production needs to proceed in order to meet on-going demand	(2), (3), (5), (7), (11), (14), (16)
		7.1.3 Mixed-Model Scheduling (a.k.a. Mixed-Model Production). Producing different products and product variations on the same line, according to the daily anticipated demand, to avoid inventory accumulation	(2), (5), (14)
		7.1.4 Under-Capacity Scheduling. Less-than-full-capacity scheduling of the work force to ensure time for quality improvement, maintenance and for adhering to daily schedule in the light of uncertainty	(2), (4)
		7.1.5 Visual Control of the Shop Floor. Making information about production and daily activities visually available in a timely and regular manner on the shop floor (e.g. Safety, Cross Training, Production status and measures, Defect/ scrap rates, Housekeeping)	(2)
		7.1.6 Line Balancing through: - Levelled schedules for smoother production flow (e.g. Heijunka box) - Bottleneck/ constraint removal - Reassignment of operators to balance workload	(5), (6)
	7.2 Pull Flow Control. Pull is a production system that explicitly limits the amount of work in process (WIP) present in the system	7.2.1 Kanban (Japanese word for card) is the mechanism of pull in the form of cards, balls, containers, etc. that is used to authorize the movement or production of parts, and as a result prevents the accumulation of WIP in the production system beyond a pre-determined limit	(1)-(3), (5), (7), (10), (11), (13)-(16)
8. Supplier Management	8.1 Supplier Selection and Evaluation	8.1.1 Reducing Sources. Variability in supplier performance is managed by creating a dependable and involved supplier base that consists of a few key suppliers (no single-sourcing) with long-term cooperative relationships. Active steps are taken to: - identify the degree of fragmentation of supplier hierarchies in each category and - create larger subsystems from fewer suppliers (e.g. modular sourcing)	(1), (7), (11) ,
		8.1.2 Reducing Distances. The key suppliers are in close proximity to the customer's plants, facilities, etc.	(11), (14)

Dimension	Practice	Tools and Techniques	Source(s)*
		8.1.3 Total Cost Supplier Evaluation. Suppliers are evaluated based on total cost and not per unit price	(2), (13), (11)
	8.2 Suppliers Coordination and Communication	8.2.1 Frequent and regular contacts are established with suppliers, for rapid communication, joint problem solving and rapid decision making, e.g. - Suppliers frequently visiting plants and vis-versa, - Direct communication links between buyer and supplier production schedulers, - Corporate level communication exists on important issues with suppliers	(11)
		8.2.2 Regular feedback is provided to suppliers about their performance on quality and delivery performance	(11)
		8.2.3 Early information exchange with suppliers on production/ service plans, orders and inventory, with electronic means e.g. Electronic Data Interchange (EDI)	(2), (7), (14)
		8.2.4 Key suppliers are linked with the company by a pull system	(17)
	8.3 Supplier Cooperation and Development	8.3.1 Long-Term Contracts. The key suppliers develop long-term cooperative relationships and contracts, including contractual commitments from suppliers to annual cost reductions	(2), (11), (14), (17)
		8.3.2 Supplier Development. A formal supplier training and certification program is provided and actively used	(11), (14), (17)
		8.3.3 Supplier Involvement in Product Design and Development and Quality Improvement programs. Suppliers are directly involved in design and cost improvements and share business risks and opportunities	(2), (14)
	8.4 Supplier JIT Delivery	8.4.1 The key suppliers deliver on JIT basis (same applies within workstations), frequent deliveries in small quantities at the exact time, place and quantities needed	(11), (13)-(15), (17)
		8.4.2 Highest quality is achieved by establishing standards (e.g. standardized containers) and joint quality control procedures (e.g. Quality at the Source practices) with suppliers	(2), (7), (14)
		8.4.3 The key suppliers provide minimum buffering costs, by - managing the company's inventories, e.g. continuous replenishment and vendor managed inventory - maintaining spare capacity to cope with uncertainty, e.g. open orders remain in the system available to be filled in, deliver on short notice	(2), (10), (11), (14), (17)

* Source(s): (1) Karlsson and Ahlstrom (1996), (2) Panizzolo (1998), (3) Fullerton and McWatters (2001), (4) Hopp and Spearman (2001), (5) Fullerton *et al.* (2003), (6) Shah and Ward (2003), (7) Yasin *et al.* (2003), (8) Brah and Chong (2004), (9) Hines, Holweg and Rich (2004), (10) Hopp and Spearman (2004), (11) Shah and Ward (2007), (12) Schonberger (2007), (13) Pont *et al.* (2008), (14) Anand and Kodali (2009), (15) Mackelprang and Nair (2010), (16) Belekoukias *et al.* (2014), (17) Khanchanapong *et al.* (2014)

Appendix B: Service classification attributes

Table B.1: Service classification attributes

Service Attributes	Definition	Classification Levels	Source(s)*
1.1 Type of customer	Institutions or individual customers. Institutions refer to non-individual customers that are likely to have more diverging needs and characteristics (e.g. larger quantities, more sophisticated services, etc.)	▪ Services for Individuals, ▪ Services for Institutions	(1), (12)
1.2 Perceived risk	Perceived risk is the customer's perception, rather than objective reality, that something may go wrong in an exchange. The dimensions of risk are: functional, physical, financial, psychological, social and time risk	▪ Convenience services, ▪ Preference services, ▪ Shopping services, ▪ Specialty services	(20)
1.3 Service Importance	Importance is viewed as the level customer's interest in the service, the extent they think about it, the degree of importance it has to their everyday life, the amount of enjoyment it brings, their desire to keep informed for the particular service	▪ Convenience services, ▪ Preference services, ▪ Shopping services, ▪ Specialty services	(20)
1.4 Purchase effort	Purchase effort is the amount of money, time and energy that the buyer is willing to expend to acquire the service	▪ Convenience services, ▪ Preference services, ▪ Shopping services, ▪ Specialty services	(20)
2.1 Customer's Commitment	The customer's ability to switch between competing offerings. If the customer's power towards the service provider is low, then it is likely to have a high degree of commitment	▪ High, ▪ Low	(5), (12)
2.2 Necessity of customer's presence	Extent to which customers must be physically present with the service provider during service delivery	▪ Necessary, ▪ Not Necessary	(12)
2.3 Demand Fluctuations (patterns)	The extent of demand fluctuations (variations) over time. Two parameters are considered: the cycle periods of these demand fluctuations (predicted, random) and the underlying causes of them (customer habits or preferences, action by third parties, non-forecastable events, etc.)	▪ Narrow, ▪ Wide	(12)
2.4 Type of Relationship	Whether the service organization enters into a "membership" relationship with its customers (telephone subscriptions, banking etc.) or there is "no formal" relationship (restaurants, car rental, etc.)	▪ Membership Relationship, ▪ No Formal Relationship	(12)
3.1 Interaction between Customer and Service Organization	Whether the customer goes to the service organization, or the service organization comes to the customer, or the customer and the service org. transact at arm's length	▪ Customer goes to the service organization, ▪ Service organization comes to the customer, ▪ Customer and Service org. transact at arm's length	(12)
3.2 Nature of Service Delivery	Continuous Delivery of Service, Discrete Transactions	▪ Continuous Delivery of Service, ▪ Discrete Transactions	(2), (5)
3.3 Service Delivery Channel	The type and number (outlets) of the market channels used to deliver services	▪ Type (Market Network, Service Personnel, Agent/ alliance, Internal Hierarchy) ▪ Number (Multisite, Single Delivery Site)	(12), (15)
3.4 Priorities Serving rules	The rules used from the service organization to serve customers under a certain priority as they enter into the service system	▪ Reservations first, ▪ First come first serve, ▪ Shortest processing time, ▪ Emergencies first,	(8), (12)

Service Attributes	Definition	Classification Levels	Source(s)*
		▪ Limited needs, ▪ Self Service	
4.1 Object processed	The object that is processed (people, materials, information) by the service organization in order to deliver a specific service	▪ People-processing services, ▪ Possession-processing services, ▪ Information-based services, ▪ Mixed-processing services	(4), (12), (14), (15)
4.2 Direct Provider of the Service (equipment vs people)	Equipment-focused services are those where the provision of certain equipment is the core element in the service delivery. People-focused services are those where the provision of contact staff is the core element in service delivery	▪ Equipment (automated, skilled operators, unskilled operators), ▪ People (professional staff, skilled labor, unskilled labor)	(7), (13), (17)
4.3 Extent of Customer Contact	The extent of customer contact in the creation of the service. Customer contact refers to the physical presence of the customer in the system, and creation of the service refers to the work process that is entailed in providing the service itself. Extent of contact here may be roughly defined as the percentage of time the customer must be in the system relative to the total time it takes to serve him	▪ Pure Services or High contact services, ▪ Mixed Services or Moderate contact services, ▪ Quasi-Manufacturing or Low contact services	(8), (11), (13), (18)
4.4 Customer's Influence	Degree to which the consumer by his/her presence, interaction and/or participation, in some way influences the service process. The customer can influence both the design and the delivery as well as the service content	▪ Professional Service, ▪ Service Shop, ▪ Mass Service ▪ Service Factory	(10), (13), (17), (18)
4.5 Customization/ Routinization	A high degree of customization is where the service process can be adapted to suit the needs of individual customers (fluid). A low degree of customization is where there is non-varying standardized process (rigid); the customer may be offered several routes, but the availability of routes is predetermined	▪ Rigid, ▪ Fluid	(11)-(13), (15), (17)-(19)
4.6 Product/ process focus	A product-oriented service is where the emphasis is on what the customer buys. A process-oriented service is where the emphasis is on how the service is delivered to the customer	▪ Product focus, ▪ Process focus	(17)
4.7 Personnel Judgment	Extent to which personnel exercise Judgment in meeting individual needs. A high degree of discretion is where front-office personnel can exercise Judgment without referring to superiors. A low degree of discretion is where changes to service provision can be made only with authorization from superiors	▪ High, ▪ Low	(12), (17)
4.8 Value added, back office/ front office	A back-office-oriented service is where the proportion of front-office staff to total staff is small. A front-office- oriented service is where the proportion of total-office staff to total staff is large	▪ Back office, ▪ Front office	(17)
5.1 Degree of Tangibility	The extent of which a service act contains Intangible or Tangible elements	▪ Intangible, ▪ Tangible Acts	(3), (6), (12)
5.2 Individual/ Collective services	A collective service is provided whenever changes occur in the conditions of several persons, or of goods belonging to several economic units, as a result of the	▪ Individual ▪ Collective services	(2), (8)

Service Attributes	Definition	Classification Levels	Source(s)*
	activity of a sing economic unit, with the agreement of all concerned		
5.3 Ownership	Owned goods services Rented good services	▪ Owned goods services, ▪ Rented good services	(2)
5.4 Single Service/ Bundle of Services	Bundle of services is referred to additional services or elements that are added to facilitate successful completion of the primary transaction. The key advantage is that of "one-stop-shopping" for an array of services	▪ Single Service ▪ Bundle of Services	(11)
5.5 Timing and Duration of benefits	The length of time over which the change affected may normally be expected to persist	▪ Permanent, ▪ Temporary	(4), (9)
6.1 Extent to Which Supply is Constrained	The extent of which Peak Demand Can Usually Be Met without a Major Delay or Regularly Exceeds Capacity	▪ Peak Demand Can Usually Be Met without a Major Delay, ▪ Peak Demand Regularly Exceeds Capacity	(6)
6.2 Management's degree of control	Decisions that management makes regarding process design. How many controls the company has planted into the service delivery system and how many routes are available to deliver service offerings?	▪ High, ▪ Low	(21)
6.3 Perceived risk for the company	Perceived risk is the company's speculations, that something may go wrong in an exchange that could lead to loss exposure	▪ High, ▪ Low	(16)
6.4 Production (and Transaction) Cost	How much effort is required for a service to be produced by the service provider	▪ High, ▪ Low	(19)
6.5 Degree of regulation	The extent of regulations that influence the process delivery. Two parameters should be considered: the extent of regulations that influence the process and the degree of compliance with this regulation	▪ High, ▪ Low	(2)

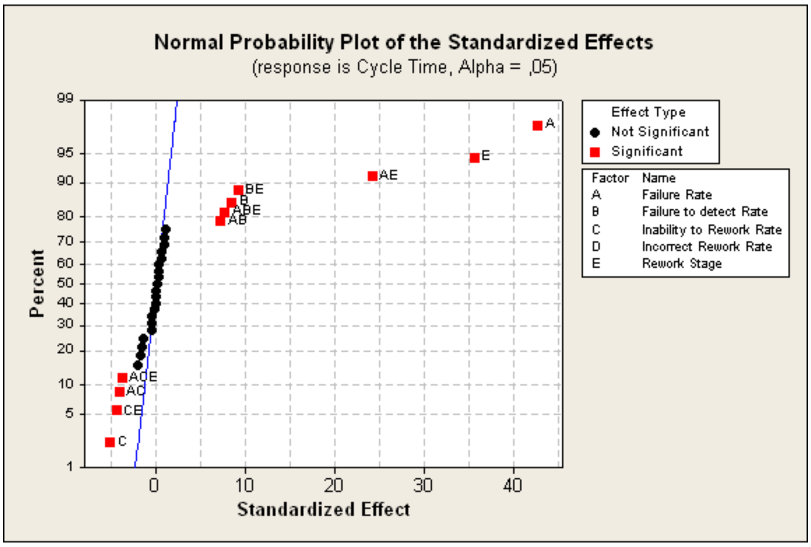
* Sources: (1) Judd (1964), (2) Rathmell (1966), (3) Shostack (1977), (4) Hill (1977), (5) Ryans and Wittink (1977), (6) Sasser (1978), (7) Thomas (1978), (8) Chase (1978, 1981), (9) Lovelock and Young (1979), (10) Mills and Margulies (1980), (11) Maister and Lovelock (1982), (12) Lovelock (1983), (13) Schmenner (1986), (14) Morris and Johnston (1987), (15) Wemmerlöv (1989), (16) Hollman and Forrest (1991), (17) Silvestro et al. (1992), (18) Kellogg and Nie (1995), (19) Tinnilä (1995), (20) Stell and Donoho (1996), (21) Collier and Meyer (1998)

Appendix C: Analysis and parameters of the quality at the source study

C.1 Statistical analysis of cycle time

In order to assess the statistical significance of the input factors and their interactions on cycle time we performed the following statistical analysis using the Minitab 15 statistical software:

- Significant factors and interactions were determined by the analysis of P-values with a level of significance set to α = 0.05 (a factor is statistically significant for all P-values less than α). The significant factors and interactions are presented in Figure C.1 (the detailed results are presented in Tables C.1 and C.2). In Figure C.1, we also show the normal probability plots and Pareto charts used to visualize the significance of the effects of the inputs on cycle time. In the normal probability plot, the further a factor, or interaction, is from the straight line, the stronger its effect is. In the Pareto chart, the significant effects are those that extend beyond the vertical line.
- The residual plots of Figure C.2 validate the assumptions of normality of the residuals that underpin the experimental procedure. The residual plots indicate that the model for the statistically significant factors and interactions is adequate to draw safe conclusions.
- Finally, the main effects and the significant interactions were plotted to indicate the factors with the largest main effects on cycle time as well as the most important interactions (Figure C.3).



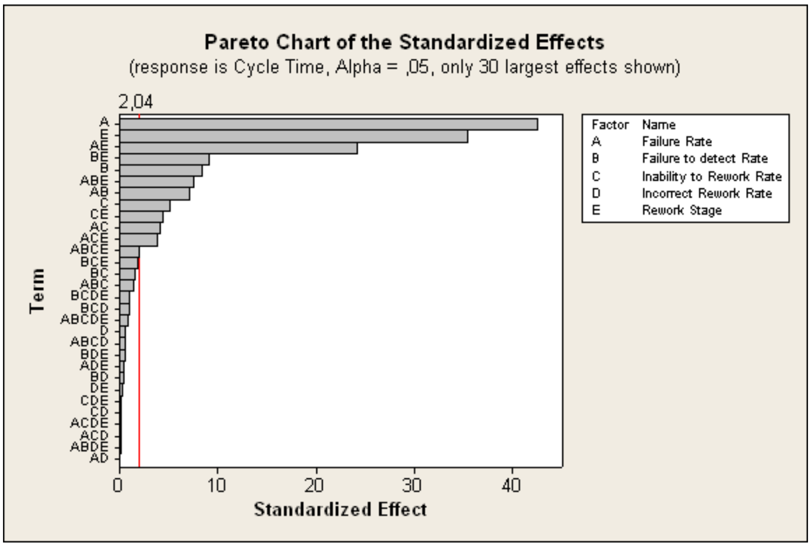


Figure C.1: Statistically significant factors and interactions for cycle time

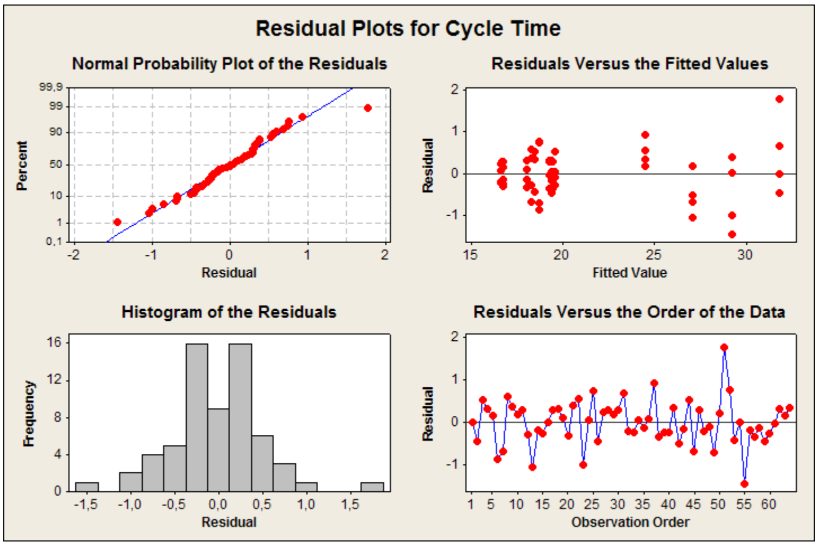
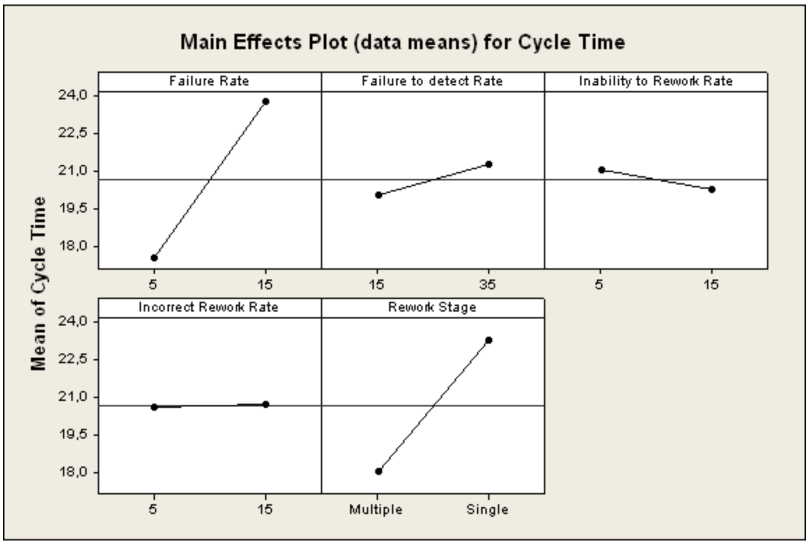


Figure C.2: Residuals for cycle time



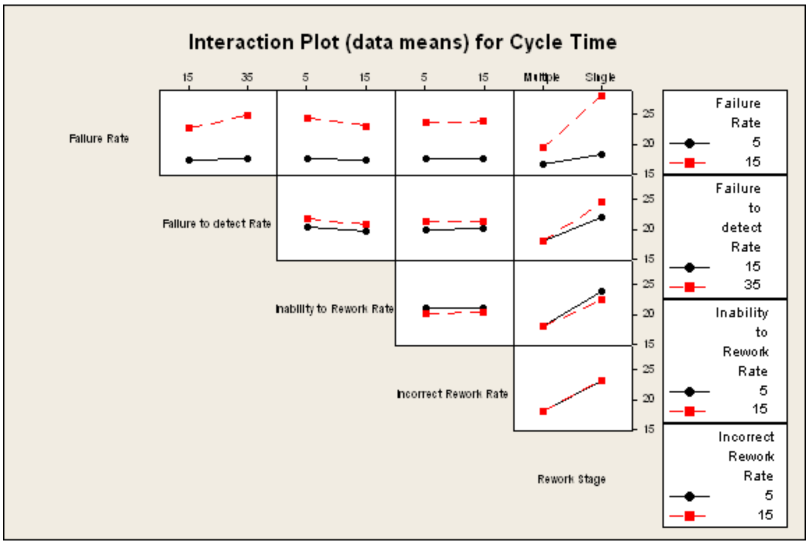


Figure C.3: Main effects and interaction plots for cycle time

Table C.1: Estimated effects and coefficients for cycle time

Term	Effect	Coef	SE Coef	T	P
Constant		206,566	0,07351	280,98	0,000
A: Failure Rate	62,618	31,309	0,07351	42,59	0,000
B: Failure to detect Rate	12,349	0,6175	0,07351	8,40	0,000
C: Inability to Rework Rate	-0,7593	-0,3797	0,07351	-5,16	0,000
D: Incorrect Rework Rate	0,0903	0,0451	0,07351	0,61	0,544
E: Rework Stage	52,239	26,120	0,07351	35,53	0,000
A*B	10,513	0,5256	0,07351	7,15	0,000
A*C	-0,6108	-0,3054	0,07351	-4,15	0,000
A*D	-0,0052	-0,0026	0,07351	-0,04	0,972
A*E	35,511	17,755	0,07351	24,15	0,000
B*C	-0,2277	-0,1138	0,07351	-1,55	0,131
B*D	-0,0696	-0,0348	0,07351	-0,47	0,639
B*E	13,426	0,6713	0,07351	9,13	0,000
C*D	0,0282	0,0141	0,07351	0,19	0,849
C*E	-0,6504	-0,3252	0,07351	-4,42	0,000
D*E	-0,0392	-0,0196	0,07351	-0,27	0,791
A*B*C	-0,2198	-0,1099	0,07351	-1,49	0,145
A*B*D	-0,0026	-0,0013	0,07351	-0,02	0,986
A*B*E	11,196	0,5598	0,07351	7,62	0,000
A*C*D	0,0136	0,0068	0,07351	0,09	0,927
A*C*E	-0,5696	-0,2848	0,07351	-3,87	0,000
A*D*E	-0,0732	-0,0366	0,07351	-0,50	0,622
B*C*D	0,1367	0,0684	0,07351	0,93	0,359
B*C*E	-0,2716	-0,1358	0,07351	-1,85	0,074
B*D*E	-0,0741	-0,0370	0,07351	-0,50	0,618
C*D*E	0,0301	0,0150	0,07351	0,20	0,839
A*B*C*D	0,0828	0,0414	0,07351	0,56	0,577
A*B*C*E	-0,2969	-0,1484	0,07351	-2,02	0,052
A*B*D*E	-0,0127	-0,0064	0,07351	-0,09	0,932
A*C*D*E	0,0276	0,0138	0,07351	0,19	0,852
B*C*D*E	0,1472	0,0736	0,07351	1,00	0,324
A*B*C*D*E	0,1277	0,0638	0,07351	0,87	0,392

S = 0,588120 R-Sq = 99,21% R-Sq(adj) = 98,44%

Table C.2: Analysis of variance for cycle time

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	5	1097,74	1097,74	219,549	634,75	0,000
2-Way Interactions	10	261,97	261,97	26,197	75,74	0,000
3-Way Interactions	10	27,69	27,69	2,769	8,01	0,000
4-Way Interactions	5	1,88	1,88	0,376	1,09	0,386
5-Way Interactions	1	0,26	0,26	0,261	0,75	0,392
Residual Error	32	11,07	11,07	0,346		
Pure Error	32	11,07	11,07	0,346		
Total	63	1400,62				

C.2 Parameters of the case study

Table C.3 presents the complete list of the parameters of the case study. These parameters have been defined either as a result of direct observations of the system or through assumptions due to the absence of related data; all assumptions have been validated by the system operators.

Table C.3: Parameters of the case study

Parameters		Description	Source
Entities	Requests (Jobs)	• All events (jobs) are of the same type (mandatory)	• Assumption
	Servers	• Two types of servers exist, the Information Processing servers and the Instruction Processing Servers. Each of the two stages comprises 4 parallel servers, each with the same skills	• Observation
Events	Arrival	• The arrival process is described by a Poisson process with a mean inter-arrival time of 10 min. (no batch arrivals)	• Observation, Historical data
	Departure	• The job departs from the system as soon as it is processed by the Instruction processing stage	• Assumption
Activities	Information – processing time	• It follows a Lognormal distribution with mean of 14.9 min and standard deviation of 9 min	• Values through observations, • Distribution assumed by the authors
	Instruction – Processing time	• It follows a Lognormal distribution with mean of 19.8 min and standard deviation of 8.5 min	
		• There is zero transfer delay between the Front Office process and the buffer of the Back Office process	• Assumption
Queues	Queue discipline	• There is a single queue at every stage with infinite capacity. Each customer request may be processed by any of the servers in each stage (the first available one)	• Observation
	Queue configuration	• A First-Come-First-Served rule is used to manage the queues. However, priority is given to failures detected in-process, which are reworked	• Observation
Failure and Rework - parameters	Failure Rate	• The probability of failure (Failure Rate) is 24% and identical for each stage, but the failures of the two stages are independent	• Observation
	Failure to Detect Rate	• This is related to the probability of not detecting the failure in-process. This probability is 70 % and identical for failures occurring in both stages	• Observation
		• All failures are detected; either immediately upon completion of a process, or after a period of time	• Assumption

Parameters	Description	Source
	by the customer. This period of time is described by an Exponential distribution with a mean of 2 days	
Inability to Rework Rate	• This is related to the probability of not been able to rework every defective request; this probability is 3% and identical for failures in both stages	• Assumption
Incorrect Rework Rate	• This is related to the probability of not reworking properly an identified failure. It equals 50% and is identical for both stages	• Observation
Severity of failures	• Each failure that cannot be reworked is classified to one of six categories as related to financial losses (see Table 4.2)	• Assumption
Rework processing time	• The rework process time in both stages follows the Lognormal distribution with the same values as the processing times in the respective stages	• Values through observations, • Distribution assumed by the authors
Rework method	• The Multiple Stage rework method was used, i.e. the defective request is only processed by the stage responsible for the failure	• Assumption

Note: in the absence of historical data the lognormal distribution have been used, a distribution commonly used in the literature for these types of activities (see Kelton, Sadowski, and Sturrock, 2007)

Appendix D: Cellular work structures and related data and parameters

D.1 Overview of the (a) functional (baseline) and (b) cellular structures

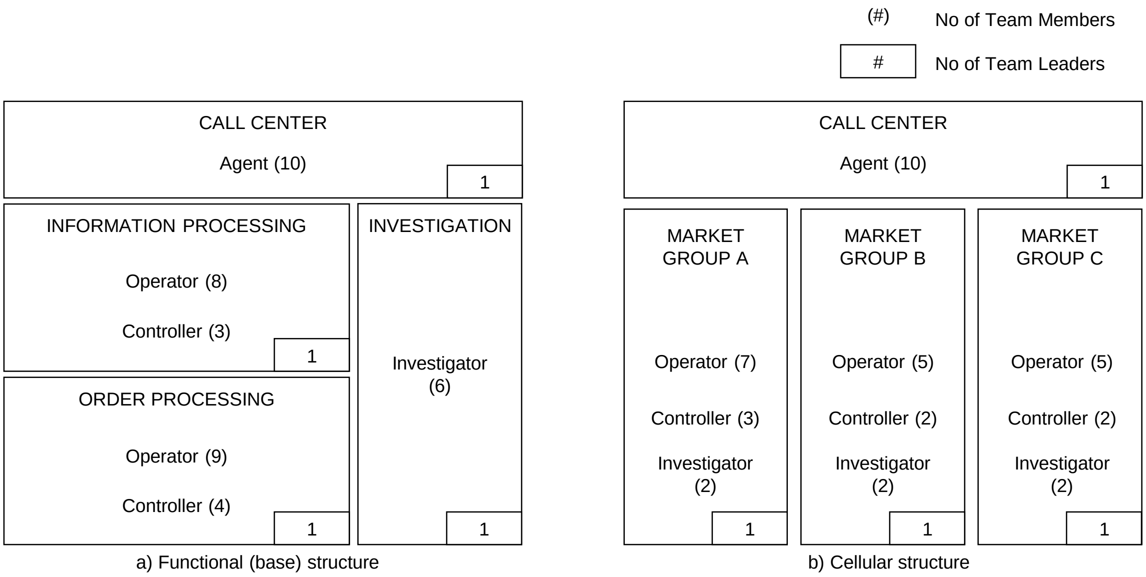


Figure D.1: Multi-skilled: operators execute an array of tasks for all markets (jobs)

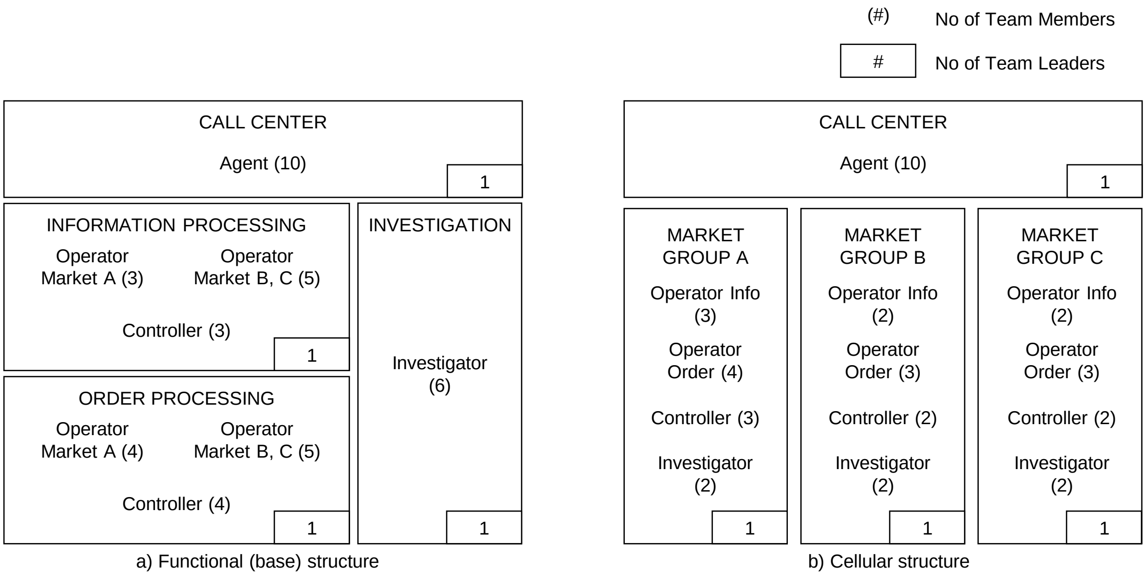


Figure D.2: Single-skilled: operators execute specific tasks for specific markets (jobs)

D.2 Load and overwork questionnaire

(example responses in italics)

Date:	*12/11/2013*	Team/ Department:	*ORDER-PROCESSING*
Interviewee Name:	*EF*	Months in current role:	*24*

1. What are the three main activities that you typically perform?
2. What is the nature of each activity (standardized/ customized)?
3. In a typical day, what is the split of the workload among these activities?
4. What is the nature of demand during the year for each activity? (peaks/ constant, predictable/unpredictable)

Q1: Activity Name	Q2: Nature of Task	Q3: Workload (%)	Q4: Nature of Demand
PAYMENTS	*STANDARDIZED*	*50*	*PEAKS/PREDICTABLE*
FOLLOW UP	*SEMI-STANDARDIZED*	*20*	*PEAKS/PREDICTABLE*
INQUIRIES	*CUSTOMIZED*	*30*	*PEAKS/UNPREDICTABLE*

5. During periods of high workload (either due to peaks in demand or due to absences), how likely it is for you to follow each of the following practice?

During periods of high workload I will…	Not At All Likely	Not Very Likely	Somewhat Likely	Very Likely	Certain
…increase my speed					*x*
…increase my overtime		*x*			
… reduce breaks/ lunch time		*x*			
…reduce time spend on tasks			*x*		

For the selected levels of workload…

6. How much you would increase your speed compared to the norm?
7. How much the probability of making an error would increase compared to the norm?

If nominal workload increases by:	Q6: Speed will increase by (%)	Q7: Errors will increase by (%)
1-10%	*0*	*0*
11-20%	*10*	*5*
21-30%	*20*	*10*
31-40%	*30*	*15*
41-50%	*30*	*20*
50%>	*30*	*20*

In case that fatigue sets in…

8. How much you would reduce your speed compared to the norm?
9. How much the probability of making an error would increase compared to the norm?

Impact of fatigue when you…	Q10: Speed will decrease by (%)	Q11: Errors will increase by (%)
start becoming tired	*0*	*0*
are tired…	*-15*	*5*
are extremely tired…	*-20*	*10*

10. What are the typical tasks that you spend less time when workload is high?

Reconciliation for payments older than 2 days, *Complex customer inquiries, Improvement Projects*

D.3 Parameters and values of the simulation models

Table D.1: Parameters and assumptions of the simulation models

Parameter	Stream*	Functional	Cellular
Arrivals	Across streams	Mean arrivals based on historical data (previous year) following the exponential distribution	In addition, arrivals are allocated 40% for Market A and 30% for each B and C
Processing time, quality	Across streams	Mean values based on planning and observations (40 hours). Distribution and standard deviation based on authors' assumptions and in the absence of historical data. It is noted that the lognormal and triangular distributions are commonly used in the literature for these types of activities (see Kelton, Sadowski, and Sturrock, 2007)	
Operators - Skills	Across streams	Similar capabilities in performing jobs w.r.t. mean processing time and quality rates across all tasks	
Operators - Availability	Across streams	Based on staff actual absenteeism and overtime data for each month of the simulation period	
Organization and process flow	Across streams	All jobs are processed in the order that they arrive (first-in, first-out)	
	Corporate actions	Errors are sent back upstream for rework	The position identifying an error corrects it, thus, two hand-over tasks are eliminated
	Customer queries	Two team leaders approve final response to the customer	One team leader approves response to customer; thus, role and step of investigation team leader is eliminated
Setup time	Across streams	Setup time is a fraction (20%) of the processing time	
Market-setup	Corporate actions	Needed, every time there is a switch to a job from different market	Not needed, since jobs are grouped per market
	Customer queries	Identical to above	Identical to above
Job-setup	Corporate actions	Not needed, jobs are grouped per job type	Needed, every time there is a switch to a different type of job
	Customer queries	Needed (for investigation), every time there is a switch to a different type of job	Identical to above
Interaction intensity	Across streams	The mean time to rework assumed to be equal to initial processing time	
Inter-unit interaction	Corporate actions	Exists between information and order processing	Does not exist, since information and order processing units are integrated
	Customer queries	Exists between call center, operational units and investigation	Exists between call center and the three market cells
Intra-unit Interaction	Corporate actions	Exists between operators and controllers	Exists between operators and controllers
	Customer queries	Does not exist	Exists between processing and investigation operators
Average Utilization	Across streams	76%	66%
Simulation period	Across streams	62 business days (three months), during eight-hour shifts with 20 days warm-up period	

* Corporate actions - queries

Table D.2: Processing time, quality rates and experimental factors used in simulation modeling

Stage	Unit-Role	Job	Quality Rates (Probability)		Processing time (Distribution, Mean, Stdev)*	
			Value (%)	Experiment Factor	Value (min)	Experiment Factor
Information Processing	Info-Operator	Follow up missing info	30	-	LOGN(6,6)	-
		Process information	100	-	LOGN(13.5,13.5)	STDE, STRA, STRE
	Info-Controller	Check information	100	-	LOGN(9,9)	STDE, STRA, STRE
		Missed errors	15	STDE	-	-
	Info-Operator	Correct information	20	STDE	LOGN(13.5,13.5)	STDE
Instruction Processing	Info-Operator	Correct information	20	IIRE, STDE	LOGN(13.5,13.5)	STDE
	Order-Operator	Process instruction	100	-	LOGN(8,8)	STDE, STRA, STRE
	Order-Controller	Check instruction	100	-	LOGN(5,5)	STDE, STRA, STRE
		Missed errors	15	STDE	-	-
	Order-Operator	Correct instruction	20	STDE	LOGN(8,8)	STDE
Payments Processing	Info-Operator	Correct information	20	IIRE, STDE	LOGN(13.5,13.5)	STDE
	Order-Operator	Process payment	100	-	LOGN(16,16)	STDE, STRA, STRE
	Order-Controller	Check payment	100	-	LOGN(9,9)	STDE, STRA, STRE
		Missed errors	15	STDE	-	-
	Order-Operator	Correct payment	20	STDE	LOGN(16,16)	STDE
Queries solved by Call Center	Call Center-Agent	Understand call	70	-	LOGN(4,4)	STDE
		Understand written query	30	-	LOGN(7,7)	STDE
		Solve call	49	-	LOGN(8,8)	STDE
		Solve written query	21	-	LOGN(15,15)	STDE
		Correct solution	10	STDE	LOGN(15,15)	STDE
		Forward query to operators	30	-	EXPO(3)	-
Queries solved by Info (Order)	Info(Order)-Operator	Understand query	100	-	LOGN(5,5)	STDE
		Request add. Information	30	-	EXPO(3)	-
	Call Center-Agent	Follow up clients	30	-	LOGN(6,6)	-
	Info(Order)-Operator	Solve query	50	-	TRIA(3,5,10)	STDE, STRA, STRE
		Forward to investigation	50	-	EXPO(1)	-
	Info(Order)-T.Leader	Approve solution	90	-	TRIA(5,8,12)	STDE
Queries solved by Investigation	Inv.-Investigator	Understand query	100	-	LOGN(5,5)	STDE
		Clarify information	40	IIRE, STDE	LOGN(15,15)	STDE
	Info(Order)-Operator	Provide information	40	IIRE, STDE	LOGN(15,15)	STDE
	Inv.-Investigator	Solve query	100	-	TRIA(15,30,60)	STDE, STRA, STRE
	Inv.-T.Leader	Approve solution	20	-	TRIA(5,8,12)	STDE
	Info(Order)-T.Leader	Approve solution	90	-	TRIA(5,8,12)	STDE
	Call Center-Agent	Reply to customers	100	-	EXPO(3.8)	-

* LOGN, TRIA, EXPO are acronyms for the Lognormal, Triangular and Exponential distributions respectively